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Universal Interconnection Technology Workshop Proceedings

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Chicago, Ill.
July 25-26, 2002

National Renewable Energy Laboratory

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Preface

The Universal Interconnection Technology (UIT) Workshop — sponsored by the U.S. Department of Energy, Distributed Energy and Electric Reliability (DEER) Program, and Distribution and Interconnection R&D — was held July 25-26, 2002, in Chicago, Ill., to:

- Examine the need for a modular universal interconnection technology
- Identify UIT functional and technical requirements
- Assess the feasibility of and potential roadblocks to UIT
- Create an action plan for UIT development.

The UIT is envisioned as an open architecture for a standardized, highly integrated, modular interconnection technology that will come as close as possible to "plug and play" for all distributed energy resource (DER) platforms and a wide variety of applications. This technology will reduce costs by creating a large market for a core technology. Through firmware or software customization, it will provide an expansion capability with the flexibility to adapt to a variety of needs and applications. The idea of the UIT is an outgrowth of industry feedback from a planning session at the first Distributed Power Program annual review two and a half years ago; subsequent projects with the Gas Technology Institute, Encorp, and General Electric that the program funded through the National Renewable Energy Laboratory (NREL); and the DOE/NREL DER System Interconnection Technologies Workshop held July 24, 2001.

These proceedings begin with an overview of the workshop, broken down by workshop session. The body of the proceedings, also organized by session, provides a series of industry representative-prepared papers on UIT functions and features, present interconnection technology, approaches to modularization and expandability, and technical issues in UIT development as well as detailed summaries of group discussions. Presentations, a list of participants, a copy of the agenda, and contact information are provided in the appendices of this document.

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Table of Contents

List of Figures

1. Workshop Overview

At the Universal Interconnection Technology (UIT) Workshop, held July 25-26, 2002, in Chicago, Ill., industry representatives presented papers on UIT functions and features, present interconnection technology, modularization and expandability, and UIT development issues. This overview provides a synopsis of each paper, notes and comments from speaker presentations, and selected participant questions in response to these presentations. In addition, the highlights of a series of facilitated group discussions are provided.
Major findings and points of consensus included:

- Interconnecting distributed energy resources (DER) with the electric power system (EPS) is traditionally a complicated process that can be improved, simplified, and made both more efficient and less costly by facilitating the combination of functions of previously discrete components into a more standardized, integrated, and modular approach, or modular universal interconnection technology (UIT).

  Reaching consensus on the nature and definition of a UIT and its basic functions is an important step for the development of this technology. This consensus can be accomplished through dialogue among industry stakeholders, including DER manufacturers, interconnection component manufacturers, and UIT customers.

- A UIT would provide a series of functions critical for the successful integration of DER with the EPS. These functions would be made available through various individual modules, either physical or logical, which in turn would be combinable to form an integrated interconnection system as required. As processes become more standardized, additional economies of scale, increased module flexibility, and enhanced functionality will occur.

Workshop Introduction

The workshop began with a welcome from Joseph Galdo, DOE manager of Distribution and Interconnection R&D, who provided an overview of UIT background, concepts and benefits. Paul L. Lemar Jr., Resource Dynamics Corp.[1] then provided a basic definition of the UIT and outlined goals of the workshop. Participants were encouraged to discuss the UIT from the "big picture" level but also to include specific design issues, to address marketplace needs and challenges, and to determine how UITs can help lower many of the current barriers to DER.

UIT Functions and Features

Dr. Sam Ye of GE Global Research Center began this session by presenting a paper titled "Universal Interconnect Needs and Trends."

In this paper, Dr. Ye wrote that, in the future, power distribution systems now controlled by large providers of power generation will be replaced by more distributed power generation architectures. The industry is concerned about how existing power distribution systems can accommodate such a changeover within the next five to ten years. One of the key issues is distributed generation–electric power system (DG-EPS) interconnection. The interconnection issue is currently being actively addressed, led by US Department of Energy (DOE), among different communities, including regulatory and research institutes, standard organizations, utilities, and distributed generation (DG) vendors. His white paper addressed DG-EPS

[1] Copies of Mr. Lemar's and other presentations are included in Appendix A.

interconnection needs and trends from an industry perspective and showed a conceptual interconnect design.

Dr. Ye stressed the following points during the presentation:

- It is important to include the utility perspective in UIT development. The infrastructure issue becomes more prevalent as DER penetration increases.
- A UIT is important to provide a specific, simple solution for interconnection.
- The key to the UIT is modularity, which can help make interconnection more affordable.

A number of questions were asked after the presentation, including:

- *How does the GE system incorporate smaller residential customers?*
  Smaller customers are provided for by focusing on designing a common platform with add-ons based on the DER application. For software, the same code would be used with different levels of complexity.
- *How do utility standards play a part in UIT development?*
  Without standardization, utility requirements ultimately decide the nature of the interconnection system.

Dr. Ye was followed by Scott Castelez from Encorp, who presented a paper on "Emerging DER Networks."

Mr. Castelez wrote that to make UIT feasible, marketplace realities must be accounted for. Clearly, he stated, the energy delivery networks will be managed by utilities, RTOs, and ISOs. When standards for interconnection are adopted, the first iteration, such as IEEE P1547, will not be enough. Enduring standards take time to create, and utility stakeholders will remain influential. Development of new technologies is not enough. Significant policy challenges lie ahead. Further DG in general, and UIT in particular, must demonstrate new business models and value propositions to gain widespread adoption.

During his presentation, Mr. Castelez noted that:

- Encorp does not have an inverter versus noninverter mindset. Rather it has a system that can work with both tracks, as approximately 80% or more of DER is noninverter-based.
- The company employs a "one box" approach of taking existing functions, making them into firmware, and putting them together. However, interconnection is still a specialty industry.
- Encorp uses components from other companies (e.g., transfer switch from GE).
- It is important to incorporate federal regulators and legislators in the UIT development process, as "policy developments must proceed hand in hand with technology."

The following are highlights from some of the questions and answers that followed the presentation:

- *How does Encorp deal with utility requirements?*
  Generally, it seeks approval on a case-by-case basis. However, sometimes it partners with a larger firm (e.g., Basler for relays) to have a name with which the utilities are more comfortable. This can add significant cost to the project but shortens an otherwise lengthy approval process.

- *How easy is it to integrate the Encorp systems with DER?*
  Generally, it is more customized than the company would like because no standards exist and it must obtain utility approval, which can require adjustments such as those noted above.
- *What will lead to the development of a UIT?*
  Factors include energy security concerns, the need to be green, performance-based incentives, and cost performance curves driven down.

An important concept that was introduced during this session was the PC analogy. It was noted that the UIT concept is analogous to personal computers — a set of core functions and capabilities is provided by the main board; flexibility, expandability, second sourcing, compatibility, and interoperability are achieved through modularity, a common bus structure and operating system, and firmware/software that can be adapted to different configurations and applications. Defining the core functions/capabilities and the common bus or system backbone structure is key to UIT development.

Next, the attendees participated in a facilitated discussion about UIT functions and features. Over the course of this discussion, the group reached several points of consensus, which included:

- The core components of a UIT should provide for the minimum requirements of an interconnection system common to both inverter and noninverter applications.
- Defining the specific functions and features to design into a UIT is of paramount importance to its ultimate development.
- The core functions that should be included in a minimum UIT configuration are:
  - Anti-islanding
  - Autonomous operation
  - The ability to withstand the environment in which it operates
  - Power on/off
  - Power reset
  - Synchronization and verification
  - Import/export control
  - Voltage, frequency, phase angle, and current as key inputs to the UIT
  - VAR/power factor control
  - DER failure indicator
  - Testability (of the UIT)
  - Meeting all 1547 requirements
  - Self diagnostics
  - Nonvolatile set points
- In addition to the core functions, the UIT architecture should accommodate expanded capabilities and various configurations (i.e., inverter as well as noninverter systems, DER located near the point of common coupling (PCC) or DER located at a distance from the PCC, single DER or hybrid systems, central control as well as localized intelligence, and interface with utility dispatch, aggregators or enterprise energy management systems.
- Considering there are engineering trade-offs when building any device, the participants placed particular emphasis on affordability, reliability, modularity, maintainability, and testability as key features that should be included in an optimal UIT design.

Current Practice with Packages Systems

James M. Daley of ASCO Power Technologies began this session of the workshop with a presentation of his paper, entitled “www and Facility Electric Power Management.”

Mr. Daley wrote that managing the use of electrical energy is a prerequisite to cost-effective business performance. Utility deregulation has created opportunities for the facility manager to reduce the cost of electricity — not the least of which is the strategic use of installed generation capacity and emergency and standby power systems. The World Wide Web provides commerce and industry with a whole new dimension of conducting business. This paper explores the effect that the World Wide Web can and has had on orchestrating the cost-effective dispatch of alternate electric energy strategies.

Mr. Dailey emphasized in his presentation that:

- Interconnection is readily achievable and can add to grid reliability.
- Responsive control strategies and adequate protection must be developed.
- The costs of interconnection have been made more accessible through the development and use of cost-effective control strategies that use the World Wide Web communications environment.

Following Mr. Daley's presentation, Robert D. Hartzel from Cutler-Hammer Inc. presented a paper on "Associated Barriers to Distributed Generation."

Mr. Hartzel described many issues that affect the successful implementation of DG from both the customer and local utility perspective. The issues can be separated into four major categories:

- System coordination issues
- Present-day UIT systems
- Power quality concerns
- Utility/Regulating body paradigm shift.

During the presentation, Mr. Daley noted:

- Studies can be carried out by unit size range, but there will be a cost penalty.
- Present-day UIT systems have a lower cost than traditional systems but also can have higher levels of complexity. To counter this, plug-and-play capabilities will be important.
- Currently there is little incentive, if any at all, for utilities to use DER.
- A major utility concern is that distribution systems are not designed for bi-directional power flow.

Next, Paul E. Sheaffer from Resource Dynamics Corp. gave a presentation of his paper, "Overview of Currently Available UIT Systems."

Mr. Sheaffer noted that the market for DER continues to evolve. Interconnecting DER to the grid can offer several benefits, but realization of the associated benefits of DER depends on DER' successful integration into the utility or Disco EPS distribution system operations without any negative effects on system reliability or safety. UIT development would define a standard architecture for functions to be included in the interconnection system. Some third-party manufacturers are assembling systems of components to build complete interconnection systems that meet some of the UIT vision. Two types of UIT-like systems currently in development are traditional noninverter-based pre-engineered systems that allow for synchronization and parallel operation with the grid and inverter-based UIT-like systems for prime movers with DC or high frequency AC output.

During his presentation, Mr. Sheaffer highlighted that the potential size of the U.S. DER interconnection market, both for new and retrofit systems, is substantial.
The currently available UIT-like systems built into the DER unit were also discussed.

After this presentation, there was a question and answer session. Comments included:

- Utility DER acceptance may depend on familiarity — providing a single way to interface and test from a utility point of view, i.e., standardization.
- There was considerable interest in defining the costs of retrofitting an existing DER installation for interconnection.
- Existing UIT-like systems that are built into the DER unit and how they might be part of the UIT development process should be considered.
- Guaranteeing reliability and a company's reputation arises as an issue when placing one company's UIT system in another company's DER unit.

A facilitated participant discussion followed during which the issue of UIT development and utility DER adoption was addressed. During this discussion, it was noted that:

- Utility needs will play a role in the development of the UIT. Several functionalities could be included in the UIT to make it and DER more attractive to utilities. First among these is universal testability. The ability to provide ancillary services, dispatchability, and aggregatability were listed as additional functions of import.
- Utilities may find it difficult to deal with many small individual DER units, a fact that makes aggregatability that much more important. A clear financial model is important when presenting the DER option to utilities, as they need to understand clearly what DER is going to mean for their bottom line. Standardizing communication interfaces can be complicated by a utility's desire to retain its own SCADA system. Therefore, any conversation about interface standardization must include input from utilities as to their interest in and willingness to use it.

Technology Challenges and R&D Solutions

Dr. Robert Wills from Advanced Energy Systems presented a paper on "Universal Interconnection Technology."

Dr. Wills noted the main impediments to the wide-scale implementation of DER have been cost, immature technology, and safety concerns. To make DER fully viable, he stated, we need to make these devices secure, flexible, efficient and cost-effective, renewable and sustainable, and safe. The key areas that he identified for research toward a UIT were:

- A standard anti-islanding method that is proved in the multi-inverter case
- Control schemes for microgrids and intentional islands
- Certified controllers
- Test procedures
- Communications protocols and object models
- Cryptographic techniques such as SSL for use in micro-controller-based DER communications devices.

During the presentation, Dr. Wills noted:

- Security, rather than economics, may currently be the strongest driver behind DER.
- The issue of multi-inverter islanding is not addressed in IEEE P1547 and may be an issue in UIT development. Concerns were expressed about the sufficiency of UL 1741. Dr.

Wills commented that tests for this standard should be method tests rather than a performance test.
- There is a need for a utility lockable disconnect.

The following summarizes the question and answer session after the presentation:

- It was noted that the anti-islanding primer list included in the presentation is not exhaustive.
- Because much of the risk associated with islanding is theoretical, is there an acceptable level? Will this be an academic question for a while? This issue went unresolved. As a result, a suggestion was made for a separate conference on the islanding issue.

A facilitated participant discussion on "Technology Challenges and R&D Solutions" followed, in the course of which workshop participants agreed that modularity provides many benefits and should be included in any discussion of UIT development. Example module block diagrams by Dr. Sam Ye of GE Global Research Center, Resource Dynamics Corp., and Joe Koepfinger of Koepfinger Consulting were presented and discussed. The group determined that, although a comprehensive diagram must still be developed, the diagrams presented provide a starting point for discussions of how the basic functions of a UIT might be organized into a block diagram, modularity, and interfaces.

The following summarizes the important aspects of developing a UIT block diagram:

- Two paths (or subsystems) were identified: (1) power subsystem or path and (2) logic and control path — with communications and data links between the two paths.
- A key component of a UIT is having a controller that has a standardized interface with the other components of the interconnection system, so that different manufacturers' controllers would be interchangeable, providing flexibility, expandability, and second sourcing.
- Object models will be important for self-configuration and plug-and-play operation.
- Participants were unanimous in their support of standardization of UIT interfaces and the specifications of UIT functions. In contrast, participants were firm in their belief that the components and software packages should not be subject to standardization.

Finally, examining the list of UIT functions, participants indicated no differences in functionality based on the size of the DER unit. Though basic functionalities remain the same, decreasing costs is critical as this in turn lowers the size of the DER that can economically be interconnected.

Conclusions and Next Steps

Participants supported the concept of a UIT and felt that its adoption would result in lower costs for interconnection and increased use of DER. The group identified a series of "next steps" for moving forward with the development of a UIT. These steps include:

- Develop working definitions for each of the UIT functions identified at the workshop.
- Develop functional block diagrams of interconnection systems for a variety of DER configurations to aid in synthesizing the UIT.
- Convene a series of one-day workshops to develop a functional block diagram for the UIT and identify the core technology:

    - One workshop to develop a functional diagram for noninverter applications

    - A second workshop to develop a functional diagram for inverter-based applications
    - A third workshop to synthesize the inverter and noninverter diagrams into a UIT and develop a UIT requirements document.

- Develop a roadmap for further defining the individual pieces within each UIT block diagram and the interfaces among them.
- Develop a list serve for continuing discussion and work on developing the UIT.

2. Session 1: Welcome and Background

The workshop began with a welcome from Joseph Galdo, DOE manager of Distribution and Interconnection R&D, who provided an overview of UIT background, concepts, and benefits. Paul L. Lemar Jr., Resource Dynamics Corp.,[2] provided a basic definition of the UIT and outlined goals of the workshop, which included:

- Examine the need for a modular UIT.
- Identify UIT functional and technical requirements.
- Assess the feasibility of and potential roadblocks to the UIT.
- Create an action plan for UIT development.

It was also anticipated that through discussion, the group would be able to describe and prioritize efforts and identify "show stoppers" to UIT development and how to overcome them. Participants were encouraged to discuss the UIT from the "big picture" level but also to include specific design issues, address marketplace needs and challenges, and determine how UIT can help lower many of the current barriers to DER.

Background on a Modular Universal Interconnection System

Today, DER are typically connected with the area electric power systems (EPSs) through various engineering approaches using a collection of individual components. The resulting interconnection "packages" are thus not yet profiting from the numerous benefits available from a highly standardized, integrated, and interoperable technology. At the present time, interconnections tend to be highly dependent on the type of DER, the experience of the developer, the nature of the EPS, and the historical practices of the particular EPS operator. Electromechanical "discrete" relays, which have dominated traditional utility interconnection, protection, and coordination approaches, are only beginning to be supplanted by digitally based equipment.

At the same time, new advances in power electronics have led to the initial development of effective integration of protective relaying in inverter-based DER. Inverter-based interconnection systems are already highly integrated, solid-state, and have a high degree of functionality implemented in firmware or software. Similarly, the trend in noninverter interconnection systems is toward increasing integration of components, using solid-state and microprocessor-based technology, with many functions implemented in firmware or software.

An interconnection system consists of all the equipment that makes up the physical link (both hardware and software) between DER and the EPS, usually the utility electric distribution grid. The interconnection system can enable power flow in one or both directions and can provide autonomous and semi-autonomous functions and operations supporting both the EPS and the DER facility (i.e., monitoring, control, metering, and dispatch of the DER unit). Figure 2-1 shows the major components, with the interconnection system being all the components within the dashed lines.

[2] Mr. Lemar's presentation can be found in Appendix A.

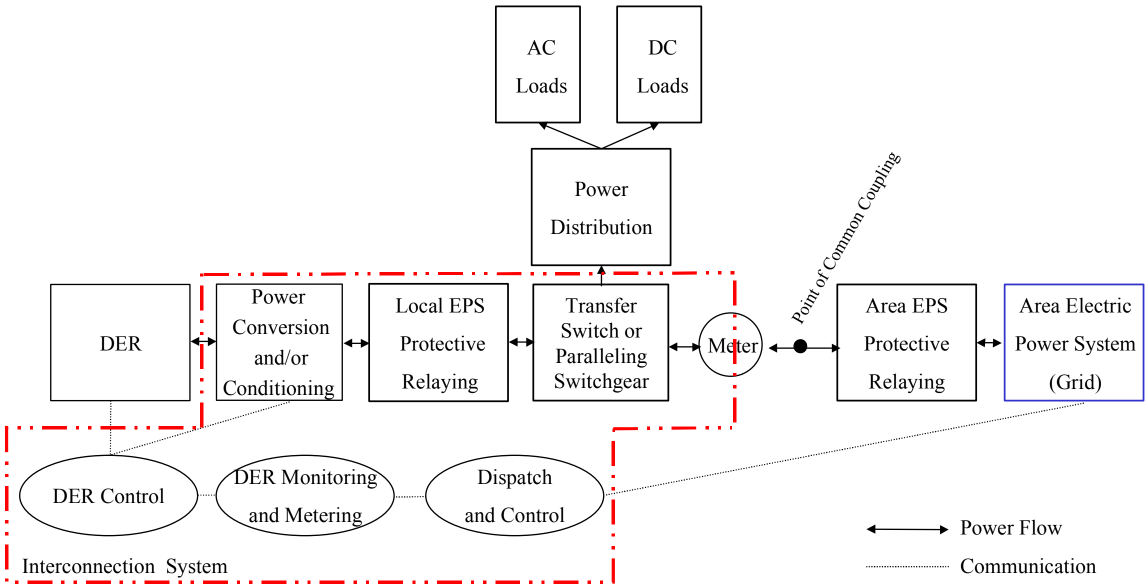

Figure 2-1. Interconnection system functional block diagram

Program stakeholders have argued from various perspectives that the traditionally complicated "art" of interconnecting DER with EPS can be improved, simplified, and made both more efficient and less costly by facilitating the combination of functions of previously unrelated components into a more standardized, integrated, and modular approach, or modular UIT. The goal of this activity is to develop an advanced modular UIT that would provide all the functions within the dashed line in Figure 2-1. Each of these functions would be made available through various individual modules, either physical or logical, which in turn will be combinable to form an integrated interconnection system as required. As processes become more standardized, economies of scale will occur in addition to increased module flexibility and enhanced functionality.
Functions that may be included in whole or part to make up a UIT system include:

- **Power Conversion and Conditioning**
  - Power Conversion – If necessary, the power conversion functions would change one type of electricity to another to make it EPS-compatible. For example, photovoltaics, fuel cells, and battery storage produce DC power, and microturbines produce high-frequency AC.
  - Power Conditioning – This function provides the basic power quality needs to supply clean AC power to the load.

- **Protection Functions** – The protection functions monitor the EPS PCC and the input and output power of the DER and disconnect from the EPS when normal operating conditions do not exist per IEEE P1547. (Note there is both an opportunity and an intention in the next generation of P1547 to develop procedures for maintaining DER on the grid as support.) Examples of this are over and under voltage/frequency protective setting and anti-islanding schemes.

- **Autonomous and Semi-Autonomous Functions and Operations**
  - DER and Load Controls – These control the status and operation of the DER and any local loads. The status can include on/off and power level commands. This function can also control hardware to disconnect from the EPS.
  - Ancillary Services – These services could include: voltage support, regulation, operating reserve, and backup supply.
  - Communications – Communications allow the DER and local loads to interact and operate as part of a larger network of power systems or microgrids.
  - Metering – This function allows billing for the DER energy production and local loads.

The proposed UIT initiative rests on the premise that by combining these functions into a modular UIT, one can pursue improved system reliability and system safety plus additional functionality while reducing costs through more thorough modular systems integration. Desirable features that might be built into a UIT system include:

- Adaptability – The ease with which a system satisfies differing system constraints and user needs.
- Affordability – To have a cost that is bearable. For a UIT system, the cost of the interconnection component is a small part of the overall installed DER system cost.
- Availability – The degree to which a system is operational and accessible when required for use.
- Compatibility – The ability of two or more systems or components to jointly perform their required functions while sharing the same hardware or software environment.
- Dependability – That property of a system such that reliance can justifiably be placed on the service it delivers.
- Extendibility or expandability – The ease with which a system or component can be modified to increase its storage or functional capacity.
- Evolvability – The ease with which a system or component can be modified to take advantage of new (internal) software or hardware technologies.
- Flexibility – The ease with which a system or component can be modified for use in applications or environments other than those for which it was specifically designed. For interconnection systems, the ability to adapt to:

  - New types of DER prime movers
  - Emerging storage platforms
  - New applications (e.g., ancillary services)
  - Diverse distribution systems
  - New communications protocols.

- Generality – The degree to which a system or component performs a broad range of functions.
- Interoperability – A system that can exchange information with and use information from other systems.
- Modularity – A modular interconnection architecture divides the interconnection system into discrete components (building blocks), each performing standard functions such as the following:

  - DER control
  - Power conversion

- Voltage regulation
- Power quality
- Protection
- Synchronization
- Communications/control with load
- Metering
- Dispatch
- Area EPS communications and support.

The definitions of the modules should be generic enough to apply to both inverter and non-inverter systems, so that they have common building blocks. Not all interconnection systems will require all blocks.

- Maintainability – The ability of a system, under stated conditions of use, to be retained in, or restored to, a state in which it can perform a required function.
- Modifiability – The degree to which a system or component facilitates the incorporation of changes once the nature of the desired change has been determined.
- Portability – The ease with which a system or component can be transferred from one hardware or software environment to another.
- Reliability – The ability of a system to perform a required function under stated conditions for a stated period of time.
- Scalability – The ability to incrementally add functionality to a system without replacing it completely. Scalability means that an interconnection system designed for one application (e.g., peak shaving) may be "scaled up" by adding additional modules for a more complex application (e.g., utility dispatch).
- Survivability – The degree to which essential functions are still available even though some part of the system is down. The system withstands significant electrical voltage and harmonic disturbances.
- Vulnerability – The degree to which a software system or component is open to unauthorized access, change, or disclosure of information and is susceptible to interference or disruption of system services.

The idea of the UIT is an outgrowth of industry feedback from a planning session at the first Distributed Power Program annual review two and a half years ago; subsequent projects with the Gas Technology Institute, Encorp, and General Electric that the program has funded through the National Renewable Energy Laboratory (NREL); and the DOE/NREL DER System Interconnection Technologies Workshop held July 24, 2001. This earlier workshop reviewed the status of systems interconnection technology to determine the technology R&D needed to achieve the Distribution and Interconnection R&D's objective of a universal plug-and-play P1547-compliant interconnection technology that is applicable across DER technologies. Further work will continue to assess both the feasibility of a UIT and any potential roadblocks to its development.

3. Session 2: UIT Functions, Needed Functionality, and Features

3.1. "Universal Interconnect Needs and Trends," Dr. Sam Ye, GE Global Research Center

Interconnection Issues

Traditional nonutility-generated power sources, such as emergency and standby power systems, have minimal interaction with the electric power system. As DG hardware becomes more reliable and economically feasible, there is an increasing trend to interconnect those DG units with the existing utilities to meet various energy needs as well as to offer more service possibilities to customers and the host EPS.

However, a wide range of system issues arises when the DG units attempt to connect to the EPS. Major issues regarding the interconnection of DG include protection, power quality, system reliability, and system operation. Another complex issue is interconnection cost, which involves equipment design, industry standards, and the local utility's approval process. These are some of the issues that have been identified as barriers to the application of DG in the EPS[3]. The solutions to these technical challenges will not only help shape the future of electric power generation, transmission, and distribution systems but also have a profound effect on the economics.

To promote the application of distributed generation, the following steps need to be taken. First, a widely accepted interconnection standard is needed that will allow for a standardized, cost-effective interconnection solution. The IEEE SCC21 P1547 standard working group is currently working toward this goal. Second, new technical requirements that address the emerging needs of DG for dispatch, metering, communication, and control should be fully explored. These additional features will improve the value of DG and the performance of the system.

Current Interconnect Status

The complexity of the DG-EPS interconnect interface increases with the level of interaction required between the DG units and the grid.

- Stand-alone only – There is no interaction with the grid. No interconnect is required.
- Standby – DGs do not directly interface with the utility grid but are connected to the local system when the utility grid is not available. Therefore, the DG has minimal interaction with the grid. In this case, a transfer switch can be used as the interconnect.
- Generation of power for consumption solely for the local load – This type of DG is fully interconnected to the grid. It normally does not export power to the grid.
- DG with import/export power – This type of DG has complex interconnect requirements. These DGs are normally integrated in the EPS control/monitoring.

To meet the above application needs, a variety of interconnect products are available in the market. They can be categorized as power-carrying devices (PCD), protection and control devices, and inverters.

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[3] Alderfer, B., M. Eldridge, and T. Starrs. "Making Connections: Case Studies of Interconnection Barriers and Their Impact on Distributed Power Projects." NREL/SR-200-28053. Golden, CO: National Renewable Energy Laboratory, 2000.

Power-Carrying Devices

The power-carrying devices include switchgears such as circuit breakers, automatic paralleling/transfer switches, etc., as well as transformers for the purpose of isolation or grounding. Although the major purpose of the power-carrying devices is to conduct and break current, some of the devices have incorporated some protective functions as well. The power rating of these devices can range from several kilovolt-amperes to a few megavolt-amperes.

Protection and Control Devices

The protection and control devices include generator controllers, protective relays, etc. Increasingly, these functions are implemented by a class of device known as an intelligent electronic device (IED). These devices are microprocessor-based for programmable control and protection, such as synchronous checking, over/under voltage, over/under frequency, directional power, directional reactive power, reverse phase/phase-balance current, phase sequence voltage, voltage-restrained over-current protections, etc. Some of them have communication capabilities. Most of them, however, do not have dedicated anti-islanding control. These devices do not directly switch or otherwise directly handle the power. They are used together with power carrying devices to execute their protective and control functions.

Inverters

Another DG component important to the interconnection is the power electronics inverter. The inverter is used as power-carrying device to interconnect DG energy sources, which produce DC or AC at other than 60 Hz, with the grid. It is possible to implement most protective and control functions required for interconnection onto a single board that also controls inverter operation.

Generally, utilities have less confidence in the protective functions integrated into the inverters because these devices are not utility-grade protection hardware and because the protective functions are not independent from the power components that could possibly fail in a way that adversely affects the grid system.

Currently, different standards and requirements exist in different states for DG interconnection. It is essential for universality, modularity, and scalability to have a solution that addresses those requirements as shown in a multi-dimensional space in Figure 3-1. The DG technology can range from small photovoltaic units to large cogeneration plants. The power interface between the DG prime mover and the grid can be single-phase or three-phase power electronic converters or rotating machines. The power range can be from under 5 kW to greater than 500 kW for larger systems.

There are multiple technology dimensions in DG applications. Regulatory and market forces will drive different aspects of the technologies selected. Each stakeholder will try to minimize the interconnect cost and maximize the benefits from its own perspective. This situation could result in one or two parties incurring minimal costs while the cost is not acceptable for other parties. Eventually, it will prohibit DG from achieving widespread acceptance in practical applications.

To achieve the broadest benefits from DG, regulators and markets, including those that set the interconnect standards, have to provide the correct price signal. Those laying out capital for an interconnection will seek to incur the least cost possible by providing the bare minimum functionality required to allow their DGs to meet safety and reliability requirements. This minimum functionality may not adequately serve the broader needs of the power system, so economic rewards need to be provided to those bearing the cost to ensure that the additional functionalities beneficial to all are implemented.

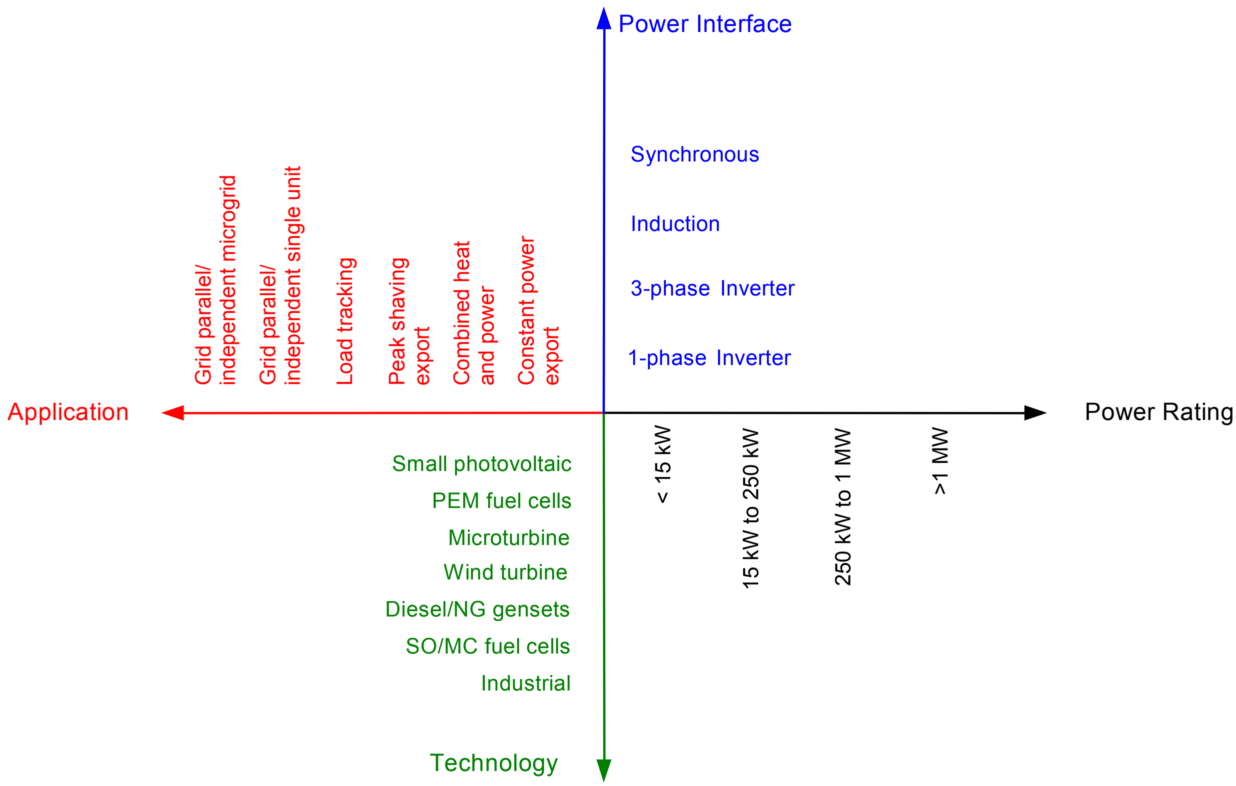


Figure 3-1. DG in a multi-dimensional space

It is observed that many solutions are targeted for specific applications. For example, some solutions are targeted for photovoltaics, while some solutions are especially suitable for rotary DG. Furthermore, it is observed that few solutions are designed such that they can be used as building blocks for providing solutions for future requirements. The goal of a new interconnect solution is to minimize overall system cost and to maximize value to the individual DG owner and the grid users in general.

Future Interconnect Needs and Trends

A conceptual design that addresses a technology-neutral, modular, scalable solution is desirable for the future interconnect solution. For widespread acceptance in the market, the solution has to involve a low cost approach. Existing solutions are so far not able to satisfy all requirements addressed in the multi-dimensional space shown in Figure 3-1. However, it should be noted that not all features would be required for all applications. Hence, a universal solution should be designed modularly, such that it can be a building block for future solutions. This would allow it to meet the need for universality, modularity, and scalability while covering all requirements addressed in the multi-dimensional space.

As noted above, a minimum of functionality may not well serve the broader needs of the power system, and yet this minimum functionality provides a basis on which to build broader and more widely beneficial functionality. A closer examination of the requirements and benefits shows that there is a natural progression of functionality of the universal interconnect. Figure 3-2 shows a diagram representing the increasing levels of functionality that are required for interconnection.

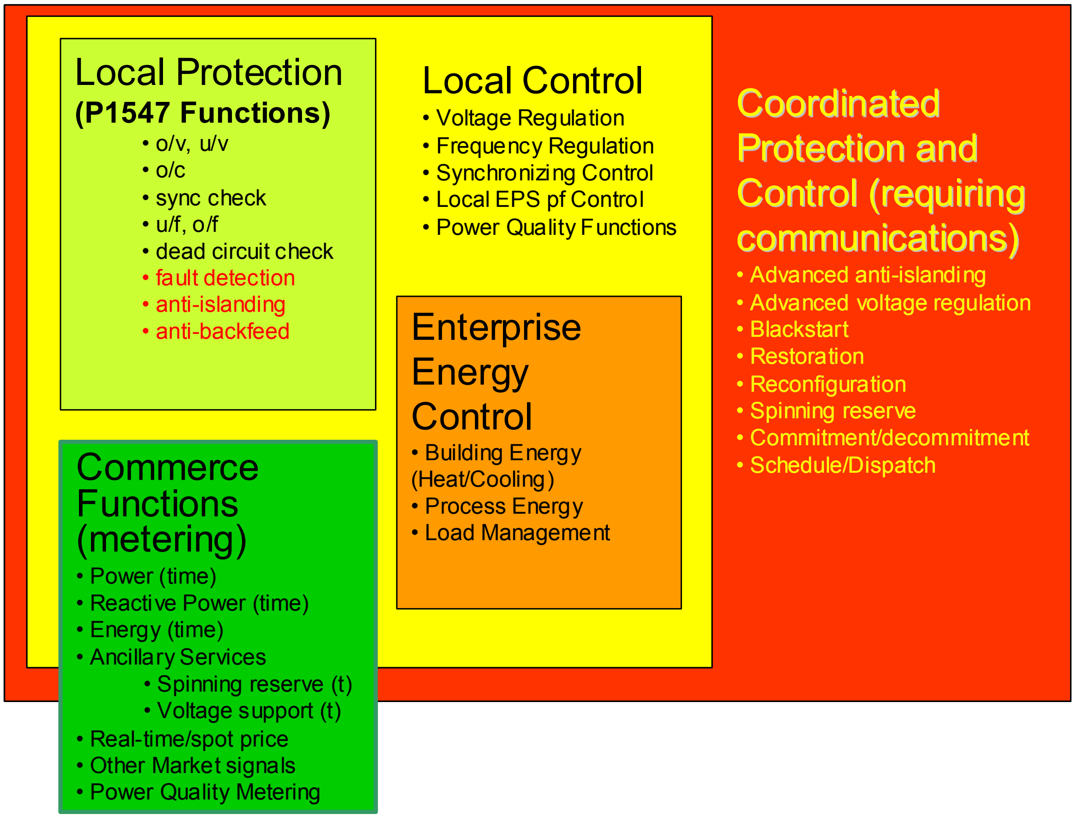


Figure 3-2. Global functionality of universal interconnection

In general, each subsequent stage of complexity wholly incorporates the functionality of the previous level. This overall, long-term concept consists of the following levels:

- Local protection
- Local control
- Coordinated protection and control
- Enterprise energy control
- Commerce

Each of these levels imposes functional requirements, which are examined in some detail in the following subsections.

Local Protection

The most basic set of protective functions that are required for interconnection are shown in Figure 3-3. These functions roughly correspond to P1547 requirements. These functions can be accomplished with local measurements. Most of the functions are simple, can be accomplished with existing relay functions, and are largely met by commercially available devices. The most notable exception is that the anti-islanding and fault detection functions required by P1547 are relatively complex and not readily available. There is no method that is effective for all circumstances. From a power system reliability perspective, these local protective functions are basically aimed at limiting potential adverse effects of DG on the host EPS.

Three functions — fault detection, anti-islanding, and anti-backfeed — impose restrictions on the DG performance that are generally incompatible with the requirements of some of the higher-level functions discussed in the next section.

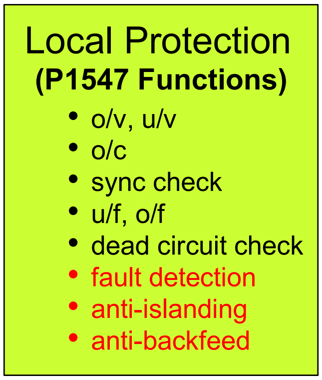


Figure 3-3. Local protection functions

Local Control

These are local functions but include a range of controls that increase the value of the DG asset. The functions, shown in Figure 3-4, push the DG performance in the EPS further.

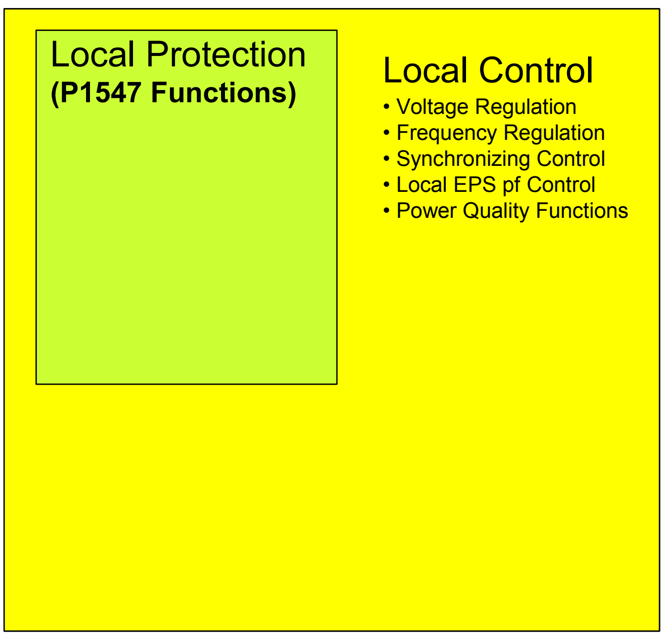


Figure 3-4. Local control functions

They represent requirements that may be incompatible with P1547, though most of them could be incorporated in the DG. Further study would be required to determine exactly which control functions need to reside in the interconnect. From a reliability perspective, these functions provide the potential for improvements for the local EPS. These functions are basic to the operation of a local EPS when separated from the area EPS. For grid parallel operation, these capabilities have the potential to be either beneficial or disruptive to the reliability and operation of the area EPS. Regulation functions, both voltage and frequency, are largely incompatible with the anti-islanding and anti-backfeed provisions of P1547. To fully realize system benefits, this level of the interconnect may require relatively sophisticated means of selecting or even determining the most appropriate control mode. Other value adding functions, most notably controls aimed at improving local EPS power quality, can be included at this level.

Coordinated Protection and Control

The ability of DG to be incorporated into a distribution system using only local measurements is very limited. Many protection and control concerns cannot be addressed without communication. The distinction between protection and control becomes unclear in a networked system, so there is little value in making the distinction.

This level of functionality, as shown in Figure 3-5, represents the range of functions that would be needed to make a system with significant DG penetration function properly and reliably.

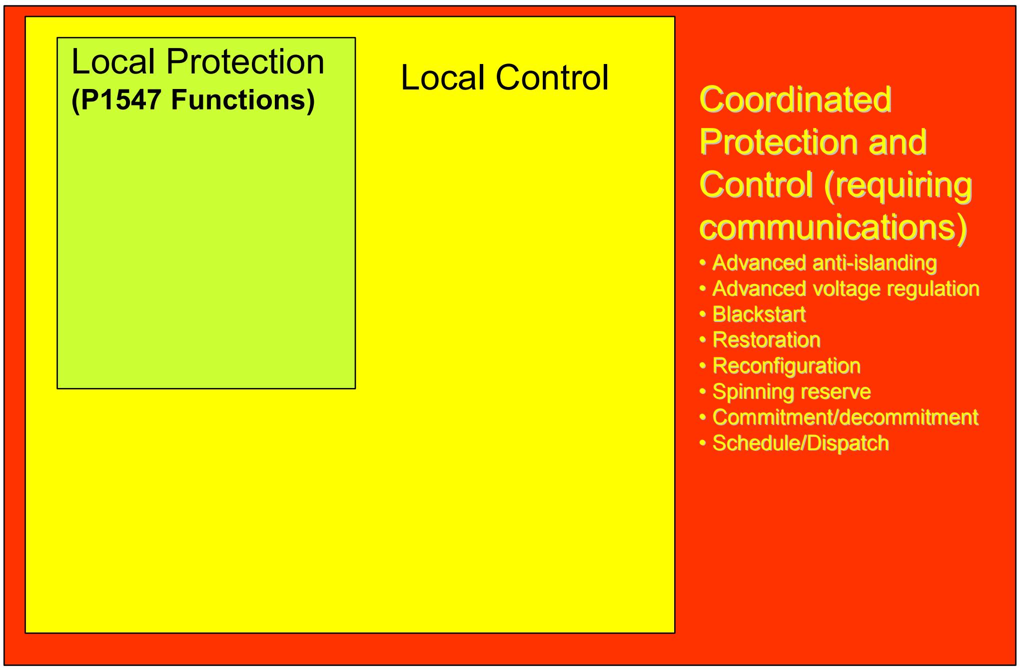


Figure 3-5. Coordinated control and protection functions

This level of functionality could include microgrids. All the functionality included in the level is aimed at improving performance and reliability of the electrical system (Area EPS). The need for coordinated protection and control is especially acute from the perspective of system reliability. Networked communications are essential to the successful integration of a significant DG capacity. Regulation and restoration of systems cannot be made solely based on local signals. Economic operation of the systems, including peak shaving and more sophisticated functions such as commitment and dispatch, will require system-level communication.

Enterprise Energy Control

To achieve the full benefit of DG, integration with other energy functions is desirable. The functions listed in this level, as shown in Figure 3-6, are complementary to the electrical protection and control requirements. Much of the economic analysis of DG shows that the most cost-effective system includes other aspects of energy management. Of particular interest is space heating and cooling, but other energy aspects may be important as well (e.g., gas and water management). This level is shown as a local function (e.g., for a building or a facility) but could conceptually be extended to multiple, physically separate facilities.

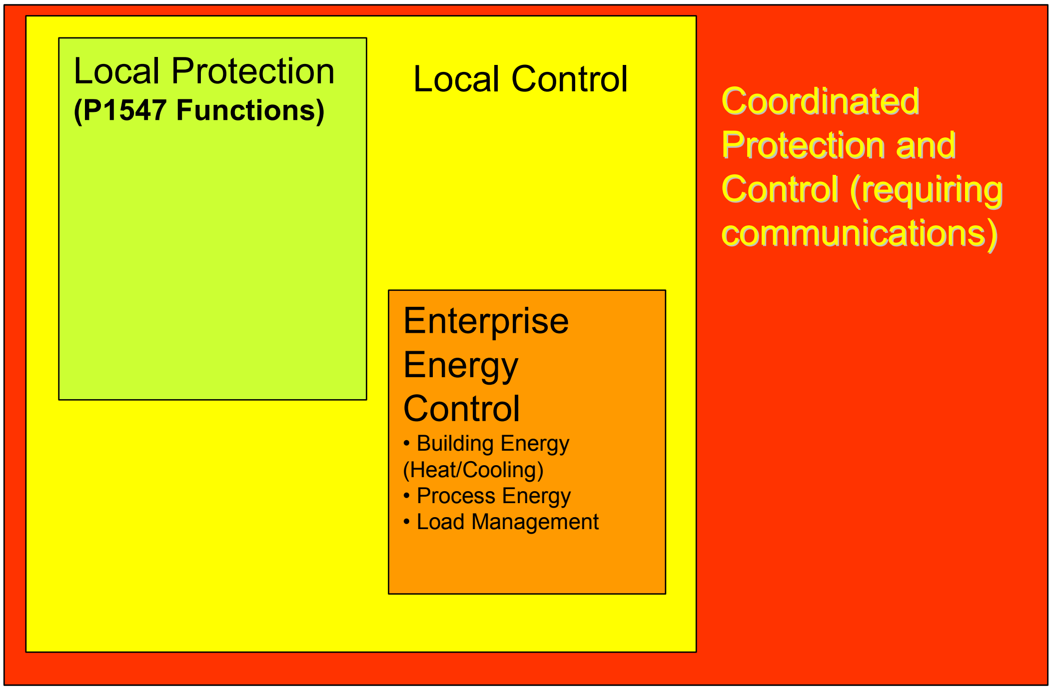


Figure 3-6. Enterprise energy control functions

Commerce

There is an entire additional layer of monitoring, metering, and control that relates to the business of owning and running DG. These functions may be localized or with significant communication and central processing (e.g., a DG aggregator or marketer). The functions listed in Figure 3-7 may be either completely localized or incorporate a broader communication system, as suggested by the placement in the figure. Market signals may be passed to various commercial stakeholders, most notably the DG aggregator selling and buying services from the system operator.

Conceptual Universal Interconnect Design

Interconnect Technology Roadmap

Having addressed the requirements for the universal interconnect design, the next questions that need to be addressed are:

- How can these different functionalities be implemented for a variety of solutions?
- What are the specific application considerations that need to be addressed?
- What is the implementation of one particular instance of the universal interconnect?

Given that the functionality illustrated in Figure 3-2 has to be implemented in the DG space shown in Figure 3-1, it is necessary to identify various embodiments of the universal interconnect. It is envisaged that this can be realized with a modular core architecture that can be adapted to different configurations depending on the nature of the DG system. Figure 3-8 illustrates a possible method through which one can arrive at the required interconnect configuration with a minimal number of decision points. The final leaves in the tree shown in the figure will provide all the modules required to obtain all the functionality in Figure 3-2 for a given DG.

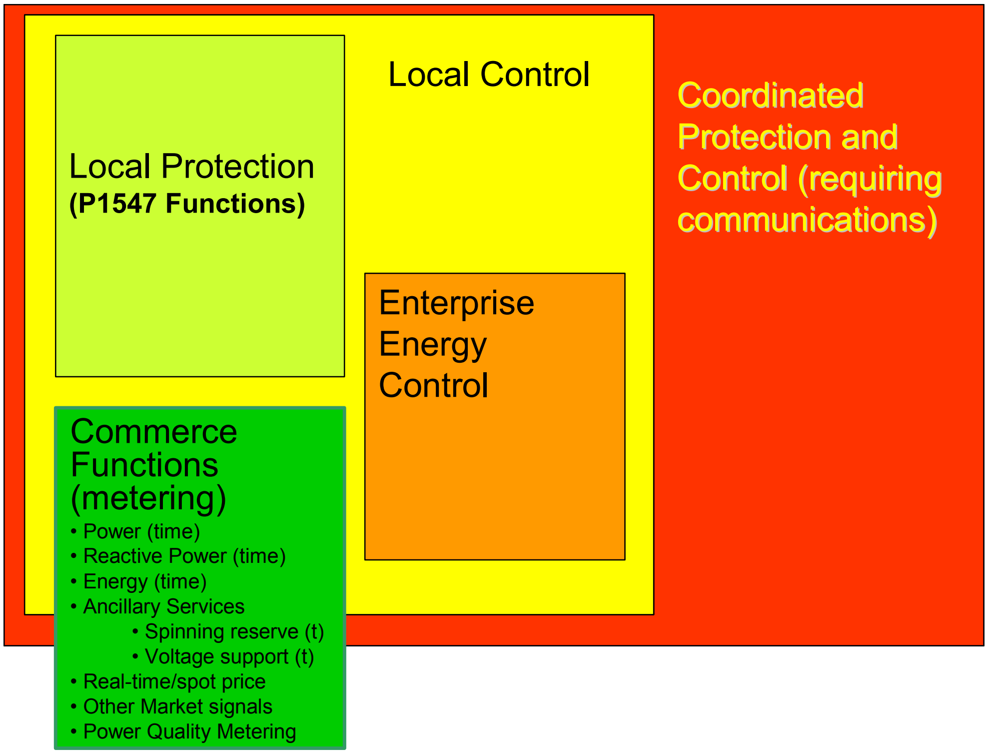


Figure 3-7. Commerce functions

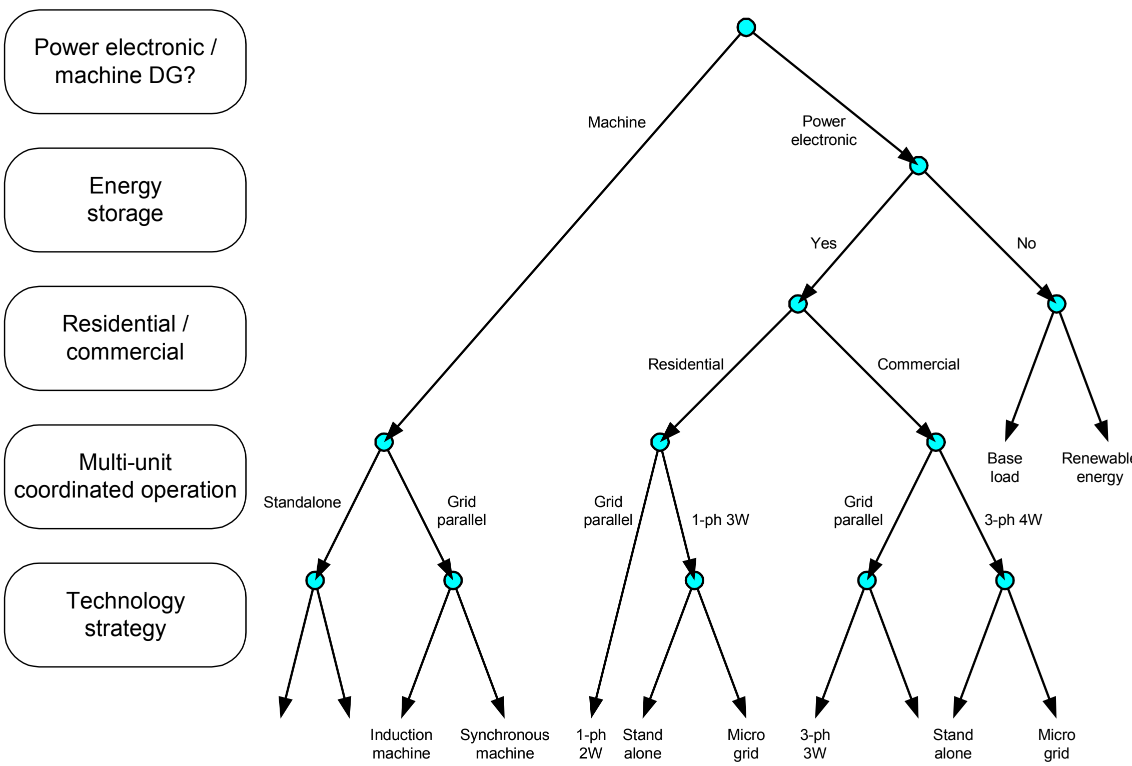


Figure 3-8. Interconnect function decision tree

As distributed generation hardware becomes more reliable and economically feasible, there will be a trend toward exploiting more of the features outlined in the preceding discussion. The interconnected DG units, and therefore the interconnection, must evolve to reflect these progressively higher levels of functionality. This increase in functional requirement provides a logical roadmap for the development of a universal interconnect. Figure 3-9 shows this evolution in three generations. The development of a universal interconnect uses a virtual test bed and a beta test site to validate each higher level of functionality.

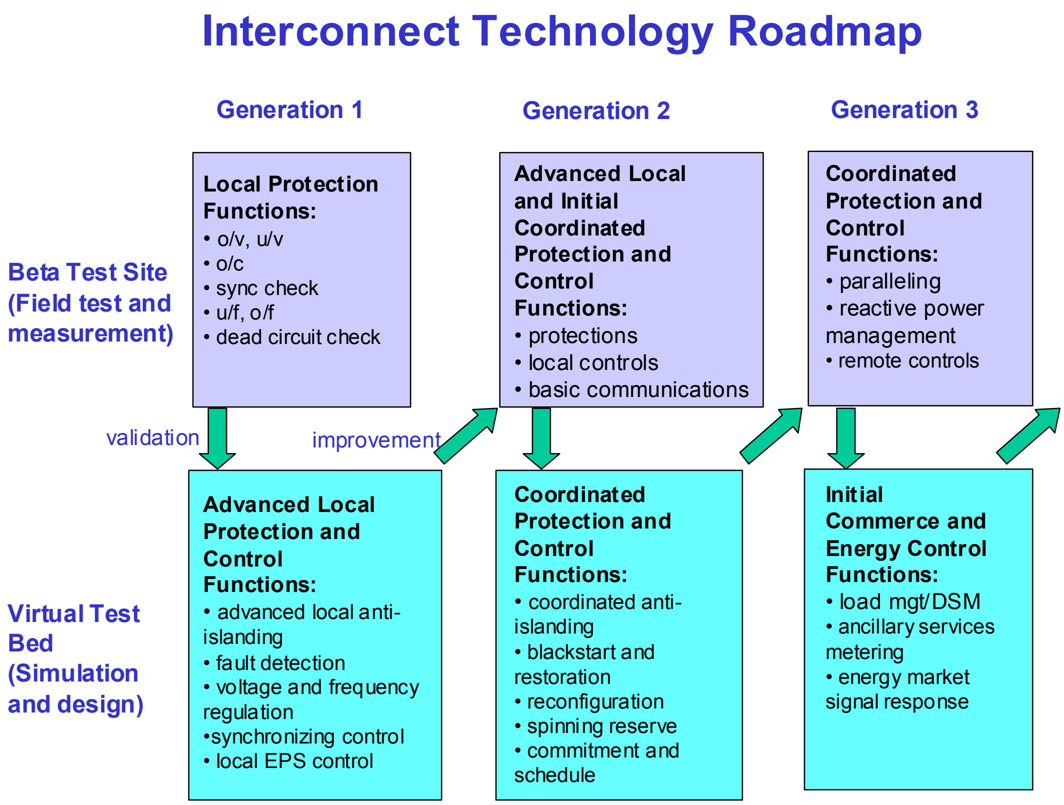


Figure 3-9. Interconnect technology roadmap

Basic Features

This section presents a conceptual interconnect design example. As discussed above, because there are various product packages existing already for Generation 1 interconnect, the example presented here is targeting Generation 2 interconnect.

The key features are outlined below and refer to Figure 3-10.

- The interconnect is a standalone box interfacing the DG and grid. It is technology neutral and can be used for different DGs.
- There are two major modules in the interconnect box. One is power-carrying devices (PCD), and the other is intelligent electronic devices (IED). The interfaces between these two modules should be normalized to allow for plug-and-play.
- There are four types of interfaces, as marked in Figure 3-10: (I1) power interface to link DG and grid; (I2) measurement interface to obtain voltage, current, and others status; (I3) control signal interface to send/receive I/O status and controls; and (I4) communication interface for the interconnect to communicate with DG and the grid.

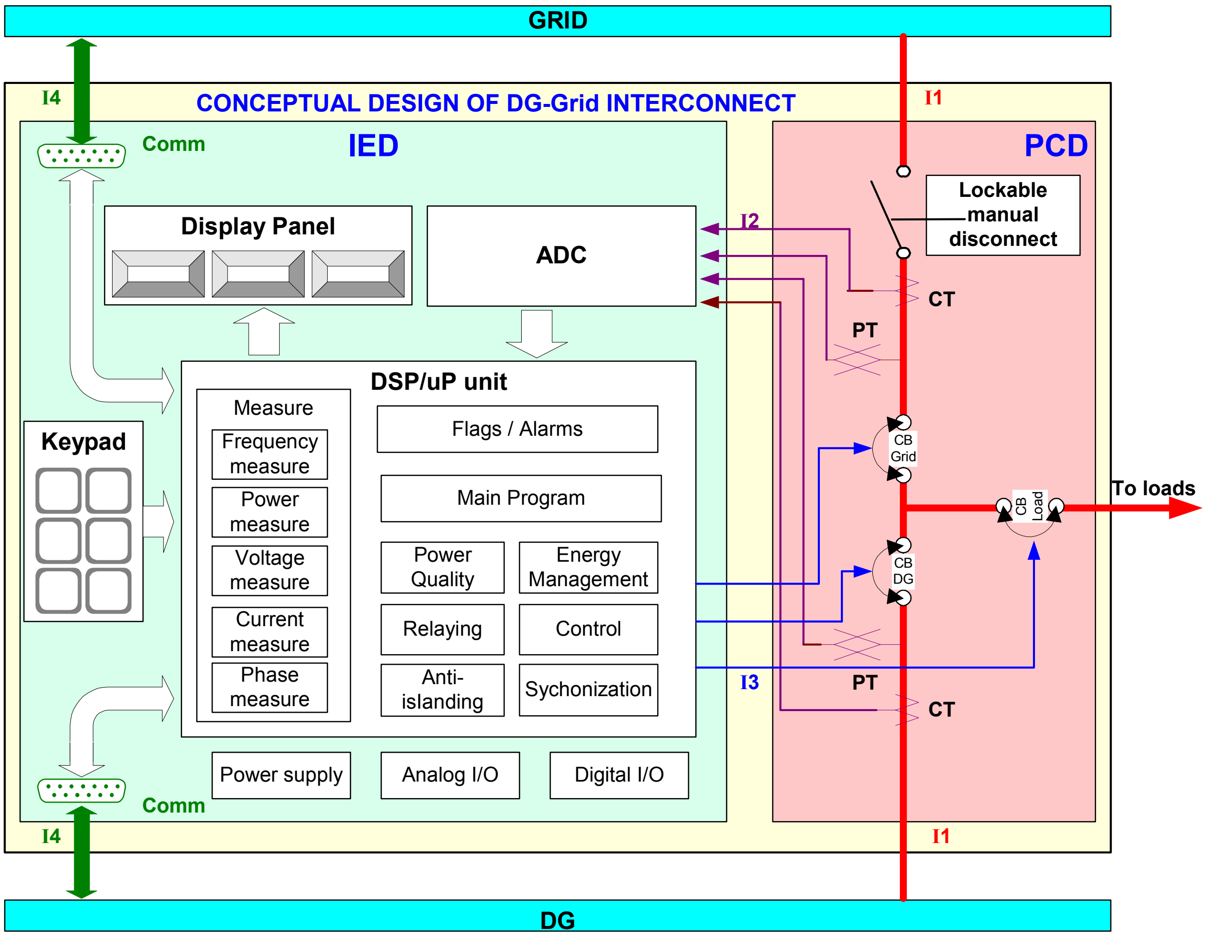


Figure 3-10. Conceptual interconnect design

- PCD components are chosen and placed based on application needs, such as single- or three-phase, peak shaving, critical load, etc. Figure3-10 shows three circuit breakers that represent only one particular case. Besides, the ratings of these devices are determined by grid voltage and DG current ratings.
- IED is the brain of the interconnect box. All protection, control, and communication software/firmware are designed in the device.
- The functions in the IED are modular to allow for reconfiguration and upgrade.

Interconnection Interfaces

Physically, the interconnect box is a standalone box with two types of interfaces to the DG and the grid. One is power interface, which connects the grid on one side and the DG on the other. The other one is communication interface, which links the DG locally or remotely and the grid remotely.

- Power Interface: The power interface could be single-phase two or three wires, or three-phase three or four wires. This will determine the number of cable/wire connections as well as sensors. Besides, the interface will determine the ratings of power-carrying devices (PCD), such as circuit breakers, and determine the ratings of sensors, such as CT and PT.

- Communication Interface: The communication interface is more complex than power interface. Depending on the communication needs, different communication protocols can be used. Physically, it could be wireless or wired. In order to be integrated with the grid and DG, it should have an open architecture and, at least at physical layer, be fully compatible with grid and DG communication protocols, such as RS series or Ethernet. The communication speed is dependent on the control needs. It is also desirable that the interconnect's communication capability is upgradeable and scalable.

Functional Modules

To make the interconnect technology-neutral, it is important to partition the interconnect into two major parts.

1. Power-carrying device — This part includes sensors and connect/disconnect devices, such as circuit breakers, switchgear, etc. The selection of these devices depends on DG-grid PCC. The grid voltage and DG power ratings must be known to select these devices. In this part, besides the power path, there are two other types of signals. One kind is sensor signals going to the IED, and the other is control signals coming out of the IED. To have plug-and-play and user-reconfigurable feature, the interface of these two signals must be normalized. For example, the secondary of the sensors is normalized to 120 V, regardless the rating of the primary, for example 480 V or 575 V. The control input for the connect/disconnect devices should also be normalized. This way, the PCD and IED can be plug-and-play regardless of the voltage and current levels at the point of interconnection.

2. Intelligent electronic device — This part is the brain of the interconnect.
   - The input to the IED includes (a) sensed signals from the PCD part; (b) communication signals from the local DG and others, such as the EPS operator, ISO, enterprise energy management systems, or other DGs; and (c) manual command from the keypad.
   - The output of the IED includes (a) control signals to open/close connect/disconnect devices in the PCD and (b) communication signals to the DG and grid, if the communications are two-way. The signals sent to the DG can be on/off, power command, etc. The signals sent to the grid can be power import/export data, etc. Monitoring signals in the display panel can be power, energy meter, harmonics, etc.
   - These inputs and outputs will be processed by digital signal processors (DSP) through A/D and D/A converters. Inside the DSP, different functions needed for the interconnection are programmed. These functions include:

     - Computation of frequency, power, etc., as a measurement function — The measurement can be used for display and computing other data and can even be accessible remotely as log data for DG and grid operators.
     - Protective relaying function, such as over/under voltage, over/under frequency, etc. — These relay functions are adjustable to meet different requirements and application needs.
     - Synchronization function — Before the DG connects to the grid, the DG output voltage and frequency should be synchronized. This function will sense the grid voltage and frequency and compare them with DG output voltage and frequency. When they are matched closely enough, the function will send a command to close the power-carrying devices for interconnection with the grid. If they are not matched, instead of waiting for the DGs voltage and frequency to approach the grid voltage and frequency naturally, the interconnect may send the grid voltage

and frequency signals to the DG as references for the DG to adjust its voltage and frequency.

  - Anti-islanding — This is a unique function of the interconnect box. Many schemes exist today. Most passive schemes can be done within the interconnect box, while some of them require additional hardware (e.g., transmitter and receiver). Most active schemes need coordination and communication with DG controls. From the modular and standardization point of view, an effective scheme built in the interconnect box would be more desirable. This function will be a key effort for Generation 2 interconnect development.
  - Control — The interconnect may need some control functions, for example, control of the power factor to improve voltage regulation. The control may need to be coordinated through the local and remote communications.
  - Energy management — This is a system-level function that optimizes the DG value. For example, it dispatches DG for peak shaving or base load based on daily energy rate, which could come from utilities or independent service operators (ISOs) through communications. The bandwidth of this control can be very low, for example, in minutes or even hours.
  - Power quality — Most standards have power quality requirements imposed on the DG and grid PCC and do not distinguish between the requirements for the interconnect and DG. One of the key values of the standardized interconnect is that it can be pre-tested and pre-certified against the standards. This feature will facilitate the DG installation process. Therefore, it may be necessary for the interconnect to measure power quality such as harmonics, DC current injection, etc. If the power quality does not meet the standards, the interconnect box can command disconnection of the DG.

- Additionally, power supplies are needed to power the chips in the IED. Additional analog I/O and digital I/O also may be needed for upgrade and expansion.
- The proposed interconnect concept is modular, scalable, and technology-neutral. This allows for maximum flexibility when interfacing to a variety of DGs for different applications.

Summary

In summary, the development of a universal interconnect can follow a natural progression of functionality. The basic requirements imposed by the various interconnection standards, most notably IEEE P1547, provide a foundation on which higher levels of functionality can be built. These higher levels of functionality benefit both system reliability and the economics of DG. Thus, the universality of the interconnection device should be viewed as a platform on which the functions required to maximize the economic and performance benefits of DG can be built rather than as a single device that will allow all possible DG to be uniformly connected to any host electric power system.

3.2. “UIT Concept Challenges,” Scott Castelez, Encorp

Introduction

In the next few years, large and robust networks that aggregate DER such as generators, flywheels, microturbines, fuel cells, photovoltaic technologies, wind turbines, and uninterruptible power supplies will gain marketplace acceptance. By design, DER assets are often sited on the fringes of a utility distribution network. Although they are close to the point of energy consumption, DER assets are not necessarily in close proximity to one another or interconnected to a common energy delivery system. Interconnection of emerging DER technologies, particularly those that are inverter-based, will become increasingly important to successfully create a robust marketplace for nontraditional generation and energy storage products.

Parallel interconnection to a utility energy delivery network is required to capture the full value of DER technologies. By design, a nonparallel installation can only create value if there is demand from a dedicated load. If a dedicated load source is idle, then the DER asset remains idle and unable to take advantage of external events. Further, a parallel interface is vital to aggregate DER components sharing the same site. Without the ability to load share, DER assets cannot be dispatched in optimal sequences. Operators of DER assets will seek the ability to prioritize dispatch sequences based on a variety of factors, including operational costs, maintenance history, fuel availability, and emissions output. Fuel cells, microturbines, flywheels, and other DER technologies require similar bridging technologies for synchronous operations.

The remote management of multiple DER technologies is a vital component in creasing a truly robust network of DER technologies. Remote management often combines both hardware- and software-based solutions. Many of the existing hardware-based devices can determine if a DER is on or off but fail to provide safe and dynamic system control. Yet, from a managerial perspective, networking devices should include analytical software packages that integrate fuel price, energy tariff data, and other external market data as triggers to control DER networks in optimal sequences. The control networks will not manage the DER devices in isolation but rather integrate the DER technologies with utility SCADA systems, customer meters, and enterprise-level management platforms. In essence, end-users will eventually demand that fuel cells, flywheels, microturbines, and traditional power generation technologies become fully integrated assets inside an enterprise-level resources management system such as SAP.

Challenges

To create these robust networks while meeting the demands of the marketplace, an aggressive research and development program undertaken by all DER stakeholders should continue. Without a UIT as an industry standard, end-users will not fully appreciate the benefits of DER technologies, and some promising DER technologies may die on the vine without ever being fully commercialized.

Challenge 1: Inverter Technology Integration

DC Interconnect Bus characterization/requirements. Inverter-based prime movers such as wind turbines, microturbines, fuel cells, and photovoltaic technologies should share a common standard to interoperate with each on a common bus. Defining the DC power bus characteristics (voltage, transients, time to start generating power/maximum power output, current characteristics, time to increase/decrease power) of each of these technologies is vital for the aggregation of multiple generation products. Defining the DC bus interface requirements of an inverter-based controller is an important step in creating and understanding the interface to a robust UIT standard design.

Interconnecting Multiple Inverters. Work should continue to define the optimal aggregation scenarios for inverter-based technologies to eliminate potential redundancies. Evaluation is needed to focus on the ability to chain multiple inverters together to manager higher-output inverter-based systems. As an example, if a single inverter-based controller is capable of handling a 50-kV system, can two controllers be combined to manage a 100-kV system? This technology evaluation should include the potential sizing of controller aggregation (25 kW, 50 kW, 100 kW, and larger). Determining the optimum controller size for inverter-based technologies will aid in a UIT interface for inverter-based technologies.

Voltage Support Technologies Required for Inverter-Based Technologies. As time delays are critical to consider for networked applications, a study of the various voltage support technologies' (batteries, supercapacitors, flywheels, etc.) output capacities, charging capacities, and power absorption technologies (for sudden load drop-offs) are required to illustrate how these technologies can interoperate with fuel cells, photovoltaics, and wind-based generation technologies. An analysis is required to determine the best control segmentation between voltage support technologies and other system controllers. Further work should evaluate load characteristics to offset sudden short-term voltage changes in an inverter-based system to aid in minimizing the size of the voltage support system. Defining a common interface for these technologies will greatly aid the UIT concept development.

Integration of Power Electronics and System Control. Further research is necessary to develop requirements and implementation technologies associated with interconnecting inverter-based technologies. Inverter and synchronous machines use different interconnect technologies, yet the market will demand that these two technologies interoperate in seamless harmony. Further work should also be done to evaluate the potential of common requirements of interconnecting both inverter and synchronous machines with the same technology. A volume-based cost analysis could determine if inverter-based electronic relays have the potential to replace the current electro-mechanical relays used with generators. The evaluation should focus on the utility interconnection interface and technologies associated with a UIT approach.

Challenge 2: Third-Party Requirement

Business economics and size analysis. As with traditional generation technologies, the cost to parallel an inverter-based unit varies in cost with size. At a certain point, smaller units face high economic hurdles, and the costs associated with interconnection become prohibitive for the majority of the residential, commercial, and industrial customers. Although niche market segments will seek to integrate small generators and storage devices with one another and the utility delivery system, serious consideration should be made to the disproportionately high costs of interconnecting these units with current technologies.

Site Integration. Evaluation should be conducted to define the various types of devices that need to be interconnected for inverter and synchronous systems. The intent is to identify a common set of I/O technologies that would allow interconnections for site-specific devices required by these two systems. This will define the common elements and features for a UIT-based system.

Enterprise Integration Demands. Owners and users of various DER technologies will seek to integrate these assets with external third-party devices, legacy IT and communications systems, and price signals from the emerging energy marketplace. To create a UIT standard interface, consideration should be given to the proper number and types of I/O ports required to interconnect DER devices with external data networks.

Next Steps and Recommendations

To make UIT feasible, marketplace realities must be accounted for. Clearly the energy delivery networks will be managed by utilities, RTOs, and ISOs. When standards for interconnection are adopted, the first iteration, such as IEEE P1547, is not enough. Enduring standards take time to create, and utility stakeholders will remain influential. Development of new technologies is not enough. Significant policy challenges lie ahead. Further DG in general, and UIT in particular, must demonstrate new business models and value propositions to gain widespread adoption.

3.3. Participant Discussion

A group discussion was initiated about the functions to be included in a modular UIT. Each of these functions would be made available through various individual modules, either physical or logical, which in turn would be combinable to form an integrated interconnection system as required. The following questions were presented:

- What is a UIT?
- What minimum set of functions should be included in a basic interconnection system? What are the optional additional capability functions?
- Given engineering trade-offs, what are the key features that a modular UIT design should focus on?

3.3.1. UIT Definition

What is UIT?

The following comments are some of those made by the group in an initial discussion of the UIT:

- The UIT should be a device that makes the interconnection transparent to both the DER and the utility.
- IEEE P1547 addresses many of the issues related to UIT development and provides a starting place for a discussion of this technology.
- Development should look not only at the present but also at the possibilities and requirements of future UIT functionalities and requirements. The ability to hook up a new DVD player to a 12-year-old television was used as an example. Although DVDs were not widely in use at the time the television was sold, the television manufacturer allowed for the possibility of future integration with this technology. The same forward thinking should be used in developing the UIT.

Ultimately, the workshop participants agreed on the following points. These points defined the course and direction of the remaining sessions of the workshop:

- Interconnecting DER with the EPS is traditionally a complicated process that can be improved, simplified, and made both more efficient and less costly by facilitating the combination of functions of previously discrete components into a more standardized, integrated, and modular approach, or modular UIT. Reaching consensus on the nature and definition of a UIT and its basic functions is an important step for the development of this technology. This consensus can be accomplished through dialogue among industry stakeholders, including DER manufacturers, interconnection component manufacturers, and UIT customers. The U.S. DOE has an important role in this process by providing a platform for the exchange of information and facilitating discussion regarding the future of the UIT.
- A UIT would provide a series of functions critical for the successful integration of DER with the EPS. These functions would be made available through various individual modules, either physical or logical, which in turn will be combinable to form an integrated interconnection system as required. As processes become more standardized, economies of scale will occur in addition to increased module flexibility and enhanced functionality.
- The UIT concept is analogous to personal computers — a set of core functions and capabilities is provided by the main board; flexibility, expandability, second sourcing, compatibility, and interoperability are achieved through modularity, a common bus

structure and operating system, and firmware/software that can be adapted to different configurations and applications. Defining the core functions/capabilities and the common bus or system backbone structure is key.

- The core components of a UIT should provide for the minimum requirements of an interconnection system common to both inverter and noninverter applications.
- Defining the specific functions and features to design into a UIT is of paramount importance to its ultimate development.

3.3.2. UIT Functionality

What minimum set of functions should be included in a basic interconnection system? What are the optional additional capability functions?

The group discussion began with participants listing and explaining functions that could be included in a UIT. The list below was generated by participant discussion:

- Testability
- Validation (operating)
- Grid abnormality
- Separation/Isolation
- Anti-islanding
- Fault protection – EPS
- Fault protection – DR
- Physical security
- Synchronization
- Autonomous operation
- Safety
- Communication security
- Manual control
- Human machine interface
- Self-supervision of the system
- Self-diagnosis
- Intentional islanding
- Voltage regulation
- Real/Reactive power
- Power control VAR
- Communications (local-DER/grid)
- Multi-mode operation
- Distribution intelligence
- Metering
- Data logging/acquisition
- Load following control
- Dispatchability
- Black start
- Import/Export control
- Frequency regulation
- Interface with EMS
- Real-time global communication
- Voltage time curve
- Ability to provide ancillary services in response to ISO
- Peak shaving control
- Ability to use storage (energy)
- Object models/self-description
- Exercising the system
- DR parameters/computer models
- Active harmonic compensation
- UCA 2.0 protocol

Voting followed in which participants were asked to distinguish between functions they consider to be minimal for inclusion in a UIT, functions they consider optional or additional, and functions they felt do not belong in a UIT. A weighted average of these votes is shown graphically in Figure 3-11.

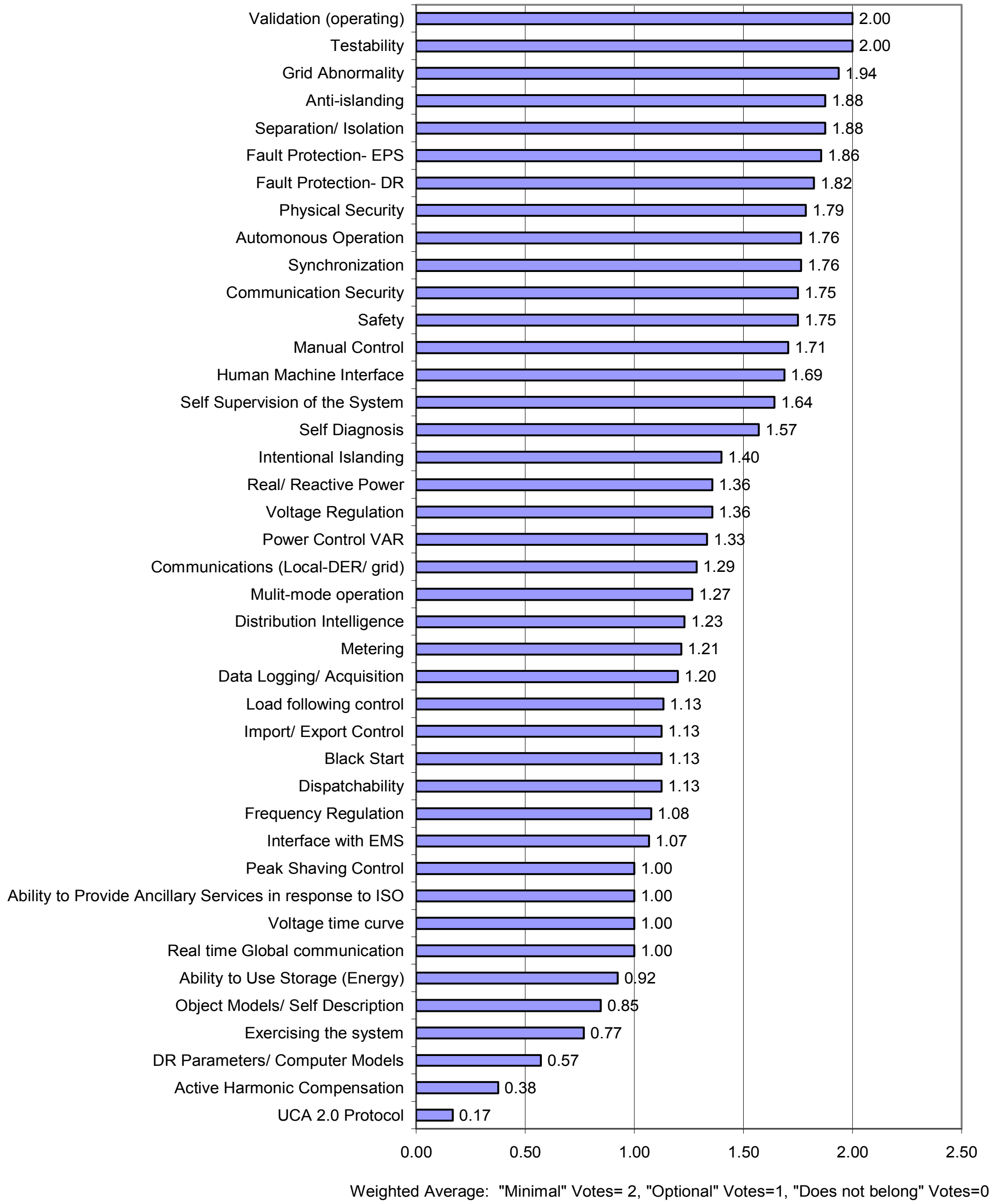


Figure 3-11. Weighted average results of UIT function voting

A second-tier discussion followed in which participants were asked to develop a final list of basic functions to be included in a UIT. The list of minimal functions to be included in any future discussion of immediate UIT development included:

- Anti-islanding
- Autonomous operation
- Ability to withstand the environment in which it operates
- Power on/off
- Power reset
- Synchronization and verification
- Import/export control
- Voltage, frequency, phase angle, and current as key inputs to the UIT
- VAR/Power factor control
- DER failure indicator
- Testability (of the UIT)
- Meeting all 1547 requirements

- Self diagnostics
- Nonvolatile set points

The following capabilities, although not considered basic functions, should be considered in the longer-term outlook for UITs:

- Intentional islanding was designated a future function that will be application-driven. Participants commented that a definition of the intentional islanding function versus the stand-alone function should be made clear.
- Physical security was determined to be important but fundamental to the prime mover rather than the UIT itself. However, the ability to physically remove communication keys from the UIT should be considered and guarded against.
- Cyber security will also gain importance in the future because, as these units will be hooked up to the grid, there will be cyber requirements to address homeland security concerns.
- Other capabilities to be considered include manual controls (i.e., manual synchronization, manual testing), modes (load shed, peak shave, stand-alone), and metering (revenue, utility grade).

In addition to the core functions, the UIT architecture should accommodate expanded capabilities and various configurations (i.e., inverter as well as noninverter systems; DER located near the PCC or DER located at a distance from the PCC; single DER or hybrid systems; central control as well as localized intelligence; and interface with utility dispatch, aggregators, or enterprise energy management systems).

3.3.3. UIT Features

Given engineering trade-offs, what are the key features (e.g., interoperability and compatibility, flexibility, scalability and expandability, reliability, survivability, affordability) that a modular UIT design should focus on?

Following the discussion on UIT functions, a list of 18 example features and their basic definitions were given to the participants. These definitions are provided in the background section of this document. Workshop participants placed particular emphasis on reliability, affordability, modularity, maintainability, and testability as key features that should be included in an optimal UIT design. Throughout the discussion, participants noted that although some features are complementary (such as modularity and affordability), others features will likely be achieved only in opposition to or at the expense of one another (e.g., in some instances, achieving affordability can compromise reliability).

The final list of 20 UIT functions considered further included:

- Adaptability
- Affordability
- Availability
- Compatibility
- Dependability
- Extendibility
- Evolvability
- Flexibility
- Generality
- Interoperability
- Maintainability
- Modifiability
- Modularity
- Portability
- Redundancy
- Reliability
- Scalability
- Survivability
- Testability/Approvability
- Vulnerability

Testability, not listed on the original list, was defined as the ability of the UIT to be tested using industry/utility standard test equipment. A standardized interface for test equipment to "plug" into, for example, was cited as being necessary, and the unit should readily offer information about values such as voltage and frequency setpoints.

Voting followed the development of this list. Participants were given nine dots and asked to place as many or as few of those nine dots beside the features they considered most important for inclusion in a UIT. Results of the voting are shown graphically in Figure 3-12.

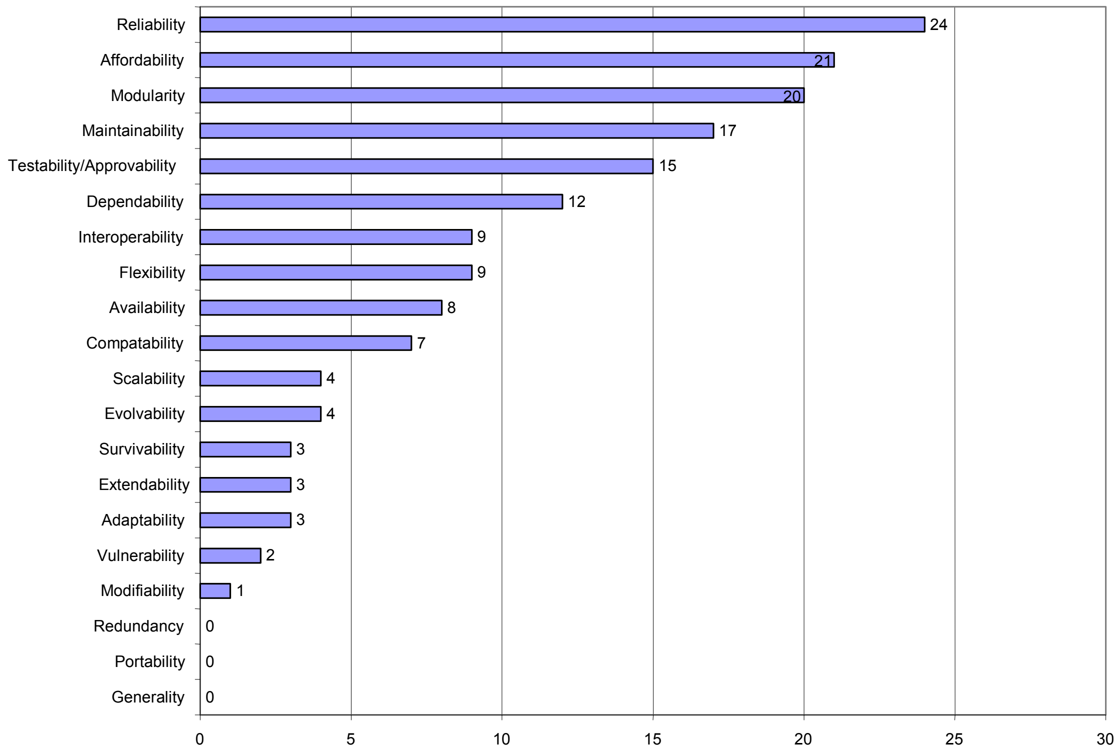


Figure 3-12. UIT features voting results and ranking

4. Session 3: Current Practice with Packaged Systems

4.1. “www and Facility Electric Power Management,” James M. Daley, PE, ASCO Power Technologies

Introduction

“eBay.com,” “priceline.com,” and others have brought the public to a new level of awareness of the Internet. Of course, engineering, science, and business have been exercising computer capabilities to their limits for decades. Microsoft asks the question “Where do you want to go today?” Accenture advertises “Now it gets interesting.” That last is probably the most telling of all. With the availability of the World Wide Web, imagination is truly the only impediment limiting departures from the common-day practice.

There is a certainty! The cost of electricity is increasing. The means to control that cost is to let it operate in the marketplace as a commodity. However, the shift from a regulated to a nonregulated industry can have some serious short-term ramifications as the course is traveled to a free market electrical environment.

Proliferation of the World Wide Web and micro-processor-based products has had a burgeoning effect on the demand for electricity. Electric demand in some geographic areas has absolutely exploded. The expansion of electric generation in some of these areas has not kept pace with the growth in demand. As a result, what was a generation safety margin became the source to carry this new demand. Thus, when demand growth in neighboring areas or natural occurrences (i.e., lack of rainfall in hydroelectric regions) reduced available generation capacity, some areas were left with little to no reserve capacity. This resulted in rolling blackouts during high demand peaks. Consequently, businesses were forced to close or find other means to meet their needs. Those businesses that had emergency or standby power systems were able to mitigate the effects of reduced availability of electric energy to some degree.

It has been estimated that there are currently “over 60,000 MW of distributed generation installed in North America in the form of reciprocating engines and gas turbines.”[4] The strategic dispatch of these resources will play a key role in maintaining business continuity and control over end-user cost of electricity as deregulation of the electric utility system moves forward.

End-User Electric Load Demand

The news media has been rife with stories and reports of excessive demands for electricity that are stressing the ability of the installed infrastructure. There are two prevalent aspects of this problem. The first is generation capacity, and the second is the ability to deliver the energy to the point of need. In its simplest form, deregulation of the electric utility system seeks to separate the generation of electricity from the delivery of that commodity. In essence, under deregulation, generation is no longer regulated. However, the transmission and distribution system remains under regulation. (There is no intent herein to debate the merits of these issues. The writer accepts this fact and examines alternatives under these conditions.) To understand the generation/transmission-distribution issues, one needs to understand the driving forces.

[4] Little, Arthur D. “Distributed Generation: System Interfaces.” Cambridge, MA: Arthur D. Little, 1999.

Figure 4-1 is a plot of the daily electric demand profile of a light industrial facility. Note that as the working day begins, the demand for electricity increases. This demand is the rate at which electricity is used. Figure 4-1 is a plot of the average demand for electricity in 15-minute intervals throughout the day. The sharp increase in the beginning of the day shows how the facility turns on. Office HVAC and production machinery is turned on just before the employees arrive and remain on until the facility closes down at the end of the day. Note that the reduction in demand at the end of the day is in distinct steps that differ from turn on. This is due to the staggered departures of employees at the end of the day. Note also that the peak demand is more than three times the quiescent demand of the early morning hours. The shape of this demand curve is quite typical for light industrial, commercial, and office facilities.

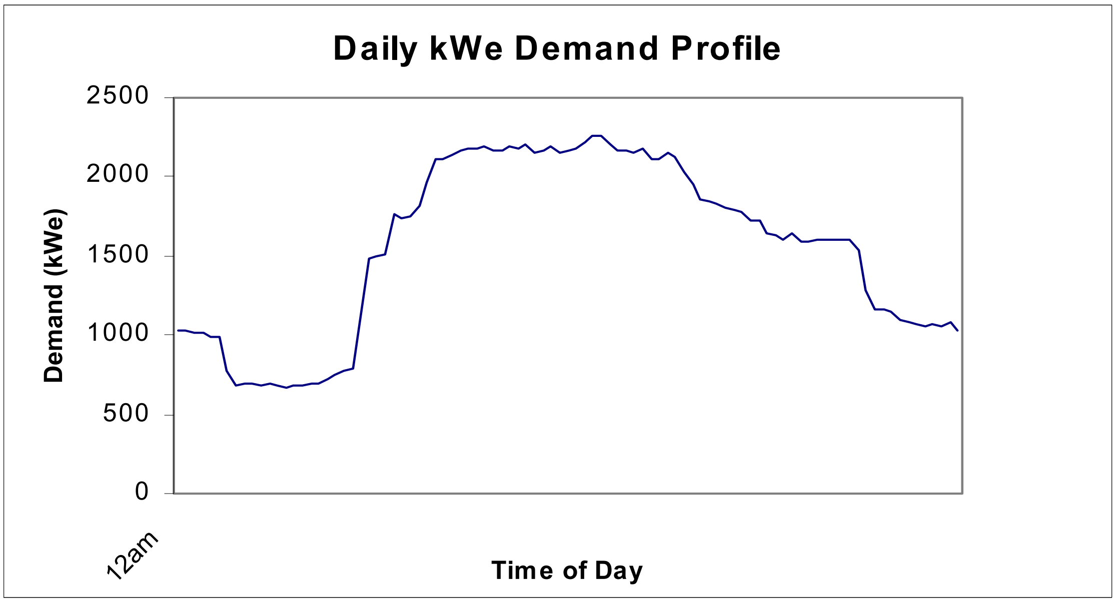


Figure 4-1. Typical electric load demand profile for a light industrial facility

The demand curve for the aggregate residential loads differs in that it peaks twice during the day. The first peak occurs in the early morning. The second peak occurs in the late afternoon to early evening. Intuitively, this is logical. The people who use the electricity are at home in the morning and evening and at work during the day.

The actual peaks of these demands are affected by a third factor. In areas where winter heating is the peak season, the maximum demand will occur in winter months and will be a function of the severity of the weather. In areas where summer cooling is the peak season, the maximum demand will occur in summer months and will be a function of the severity of the weather. From season to season, there will be considerable variations in the peak demand. From year to year, there will also be considerable variations in the peak demand.

Generation and Delivery of Electricity

There are two distinct concerns dealing with the availability of electricity at the desired point of use. Neither the generator nor the deliverer of electricity has any significant influence over where users choose to build their facilities.

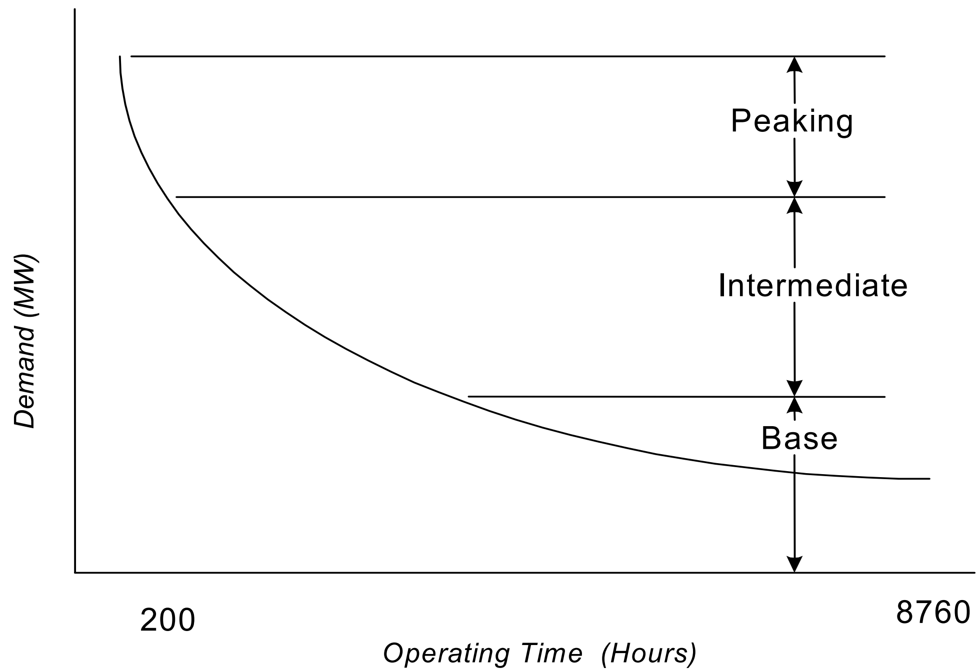


Figure 4-2. Generation yearly operating hours

Being regulated, the transmission/distribution system must provide the infrastructure to deliver electricity on demand. That is not to say that the end-user is free of any costs to install infrastructure. Because no one wants to live next to a generation station, generation is typically remote from the point of use. Because demand varies throughout the day and year, generation capacity varies. Finally, because it is physically cost-prohibitive to build one large generator to carry the peak demand, several generators are typically networked to provide power on a common power grid. Economies of scale and cost effectiveness of different generation techniques are commonly mixed to provide for a best-cost scenario. For example, nuclear, coal, and/or hydropower may form the base load generation for a power grid. Generation consisting of gas-fired turbines with combined cycle steam generation will form the intermediate generation and gas fired packaged peaking turbines will form the peak demand response generation. Commodity cost, is lowest for the base generation case and highest for the peaking. Affecting this commodity cost is the cost recovery of infrastructure to generate. What does that mean? Figure 4-2 is an approximated plot of generation operating hours during the year. The plot illustrates that base generation operates at rated capacity for most of the year. Intermediate plants operate at rated capacity for up to 4,000 or so hours each year. Peaking plants operate at capacity for up to about 200 hours each year. The cost for infrastructure of peaking plants is amortized over 200 or so yearly hours of operation. It is thus demonstrated why electricity from peaking units costs dollars per kilowatt while it costs cents per kilowatt from base generation plants. A representation of those costs is shown in Figure 4-3**.** This terse review establishes why those peak stress periods are so costly.

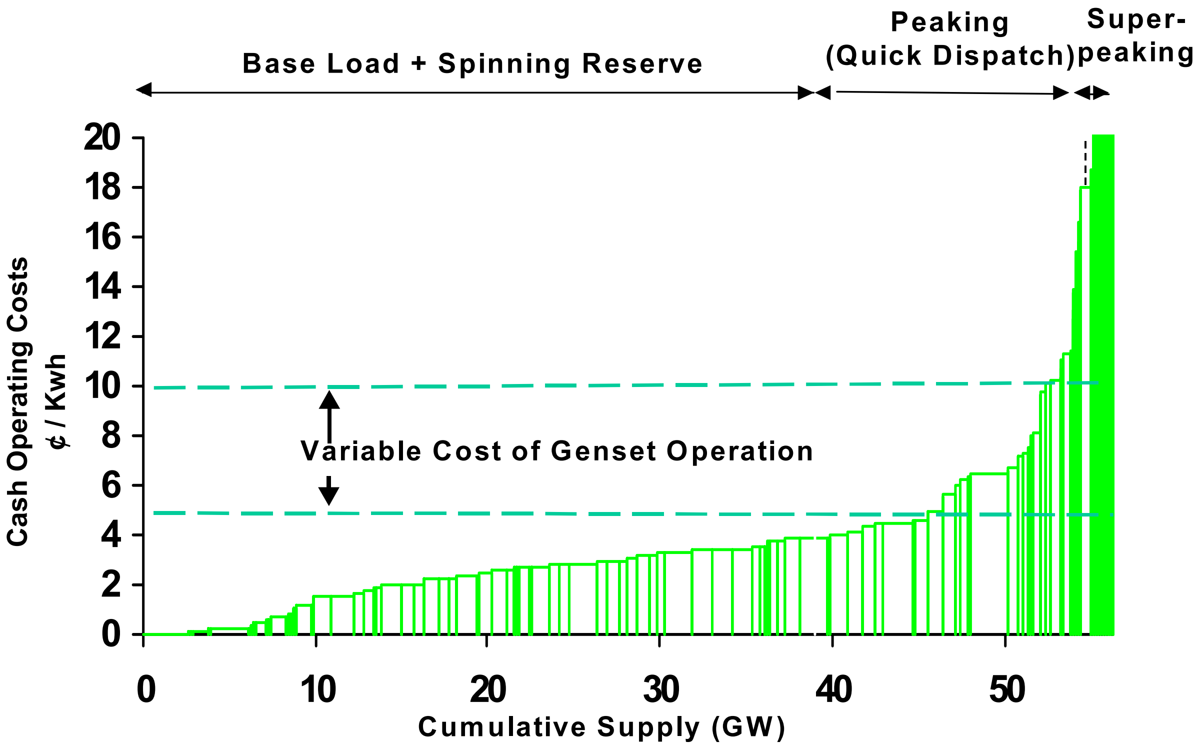


Figure 4-3. On-site generation

The National Electrical Code, NFPA 70, Art. 700, 701, and 702 address the provisions for installation and operation of emergency, legally required, and optional standby power systems. Each of these systems is independent and capable of providing power to selected loads when the utility-derived power source is inadequate. This code allows the use of these systems for peak shaving. It reads, "The alternate power source shall be permitted to be used for peak load shaving."[5] This first appeared in the NEC in the 1970s as a result of the energy crisis at that time.

As a result of major power outages in the '60s and '70s, on-site generation capability expanded. Fueling this expansion was the increasing dependence on real-time data processing and computerization of business practices. As a result, there is a tremendous installed base of generation fully capable of being brought into service to address the rolling blackout issue. As a matter of necessity, these power systems are designed to start automatically and carry their respective loads whenever the utility-derived voltage supply to their respective loads becomes unacceptable. So when there is a rolling blackout on a distribution radial feeding a facility at which on-site generation is installed, the protected loads will be restored to power from the alternate source automatically. This will occur in less than 10 seconds from the time the utility power is cut off. In code-mandated installations, these systems must be periodically, typically monthly, exercised to confirm their availability. The reliability of these systems is very high. With more than 500,000 transfer switches installed, and judging by the frequency of service calls and warranty service one manufacturer experiences, reliability of these systems is well in excess of several nines.

[5] National Electrical Code, NFPA 70, Art. 700-5 (b). Quincy, MA: National Fire Protection Association, 1998.

These systems are installed to manage risk. As such, they are somewhat of an insurance investment. How does one determine the return on investment (ROI) on an insurance investment? Given the existence of these systems and the allowance to use them for peak shaving, encouraged by incentives to reduce demand for short periods, additional investment in these facilities so that they can be brought into service during peaking periods is a viable consideration. The issue is what investment derives the best cost-benefit.

The Starting Point

The hypothesis is multifaceted:

1. The cost of the on-site generation is a sunk cost.
2. Use of the on-site generation for peaking is self-funding and yields a net positive cash flow.
3. Costs to take advantage of the peaking capability of installed generation can be recovered within three years.
4. Automation of the process is achievable with minor peripheral additions.
5. Performance can be captured and verified.

The on-site power system will come in many shapes, sizes, and configurations. There is a commonality, however, that makes it possible to resolve this multitude of configurations into three basic system types. They are:

1. Single engine single load, Figure 4-4 (a)
2. Single engine multiple loads, Figure 4-4 (b)
3. Multiple engines on a common bus, Figure 4-5.

These figures illustrate the breadth of on-site generation as installed for alternate power purposes. Taking advantage of this installed capacity for peaking will require:

- A means to dispatch
- Load control
- Verification
- Operating summary
- Integration with net neutral staffing.

Dispatching requires that the on-site generation be capable of being started and stopped on command. This command can issue from an in-house controller or be responsive to an external signal. Deregulation of the electric utility system has spurred the growth of generation aggregators. These are businesses that make arrangements with the owners of on-site generation to pool and broker on-site resources. They will aggregate several of these resources so as to achieve at least the minimum required generation capacity to permit membership in the controlling power exchange (PX) or ISO. Typically, these require a signed contract between the PX/ISO and aggregator. The aggregator will typically require that the on-site power system be made available to him for remote dispatch. When needed, the aggregator will initiate the start and operation of the on-site resource. The agreement will settle on a capacity from the host facility. It makes no difference to the electric grid whether the demand reduction is due to load disconnect or on-site power generation, load transfer. The net effect on the demand on the grid is the same. However, the host facility is keenly interested in maintaining operations. Therefore, load disconnect is not typically a viable option.

Additionally, load transfer brings with it the concern for operational transparency. Simply stated, regardless of the power source or switching, the load should not experience any transient conditions that would negatively effect its operation. Load transfer strategies are many and varied. Some of the variations are due to the unique nature of a load; some are a result of the unique approach a manufacturer may choose in product design. Some of these are to the benefit and others to the detriment of power continuity to the load. For the curious reader, a treatise on the subject of load transfer strategies can be found in a paper that was presented at an IEEE IAS conference in the spring of 1998.[6]

Given the typical control strategy of load transfer, all that would typically be required to initiate peaking load transfer would be an initiate signal to simulate the loss of utility-derived power. This signal, delivered to the transfer switch, would cause an operating scenario exactly the same as would be initiated for periodic testing to meet code availability requirements. If the transfer strategy is suitable for system test requirements, it is suitable for peaking requirements. To determine successful operation, an auxiliary contact confirming that the load is connected to the on-site generator is all that would be required. Thus, the initiation and confirmation of operation are readily achieved. What hardware is required? For the case of the single load/single generator, a simple modem and controller would suffice. If the transfer is one of the more current product designs, it may already have communications and control capability built in. If not, the equipment required to provide this is relatively inexpensive.

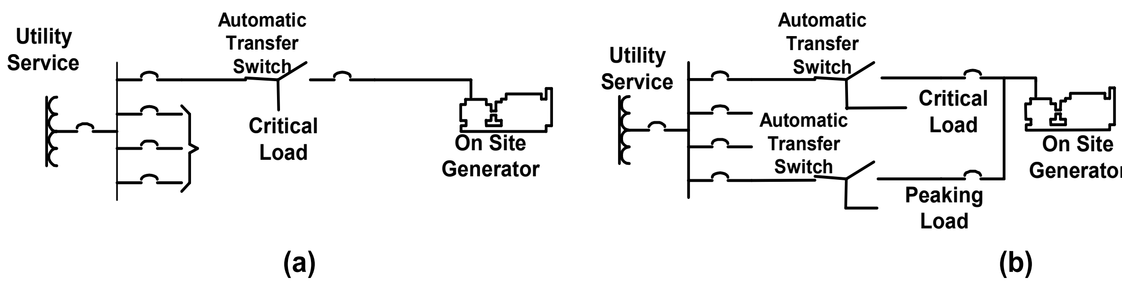


Figure 4-4. Simple on-site alternate power systems

Suppose, for whatever reason, the end-user has an issue with using the critical load for peak demand reduction (usually an emotional issue). It is likely that the savings from peak shaving will finance the cost of a second load transfer circuit specifically dedicated to peaking. Such a circuit is shown in Figure 4-4 (b). Initiation and control would be as just described.

Where the on-site generation is composed of two or more generator sets paralleled on a common bus, considerable flexibility and latitude are available. Typically, paralleling switchgear contains a programmable logic control system that is readily adaptable to expand the logic to accommodate peaking power scenarios. In this case, the initiate signal could be sent to the system controller or automatic transfer switch equipment (ATSE), whichever provides the most cost-effective scenario. Whatever the configuration, load control is typically cost effectively achievable.

When called to operate, an aggregator will be required to confirm to the PX/ISO that he has provided the amount of contracted resource. Therefore, the aggregator will require that the host facility provide a means to measure and record the energy produced by the on-site generator

[6] Daley, James M. "Load Transfer Strategies for Machine and Other Inrush Loads." *IEEE Transactions on Industry Applications*; Vol. 34, No. 6, November/December 1998.

during the required operating period. This verification will be a prerequisite for capacity payment. It should be kept in mind that the call for operation will be during those 200 yearly hours when the cost of other kilowatt-hours is in the dollars per kilowatt-hour range.

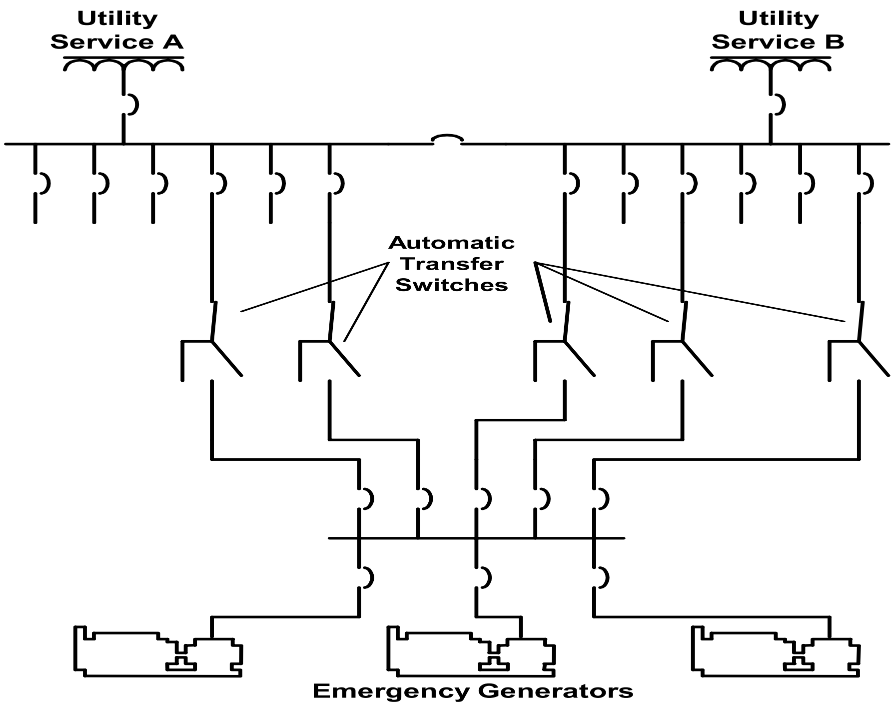


Figure 4-5. Multiple generator alternate

In response to this need, there are many means to record and communicate energy flow in an electric circuit. The site aggregator will likely have a predetermined arrangement for data collection and recording. The ideal data record will date and time stamp operations. In addition, it will record the kilowatt-hours and demand on the on-site generation and maybe even those data on the utility-derived service for the same time frame. The date- and time-stamped record of on-site generated kilowatt-hours and kilowatt-hour demand would form the minimum set of data to confirm production of electricity coincident with the PX/ISO-declared stress period. These records would confirm the operating summary.

What has been described thus far has not mentioned the need for increased staffing to provide on-site generation availability. In fact, the proliferation of data communications and software configurable equipment makes it all but a certainty that additional staffing will not be required. Here is where the Internet comes into the picture. It is useful to explore the possibilities.

Single Generator/Single Load

Where the transfer switch is an open transition double throw device, only the load on that switch can be removed from the utility-derived service. Therefore, load reduction will only equal the real-time load (active load) served by that ATSE. Where the load transfer switch is either a closed transition or delayed transition transfer device that can be used as a paralleling device, the potential to take full advantage of the generator kilowatt rating exists. Assume the latter case.[7]

[7] Note: The writer suggests that the generator be run at 80% of its standby rating when operated in the peaking mode.

Figure 4-6 represents a single load/single generator application in which the transfer switch is capable of parallel operation of the generator with the utility-derived service. To adapt this installed resource to distributed generation service, one would add protective and data collecting means to the utility- and generator-derived feeders. Additionally, a controller would be added to orchestrate the operation on command. As Figure 4-6 illustrates, a power manager has been added to the utility and generator feeders, and the soft load controller (SLC) has been added. There are two important points to be made here. The power managers include protective relaying functions whose principle role is to separate the power sources immediately on the occurrence of a disturbance.

Should any failure occur in the control scenario, the installed ATSE reverts to being a transfer switch, and operation for distributed generation is terminated. The ATSE can be configured to keep the load on the generator until the need for peaking is terminated. In that event, the load reduction is equal to the active load on the ATSE circuit.

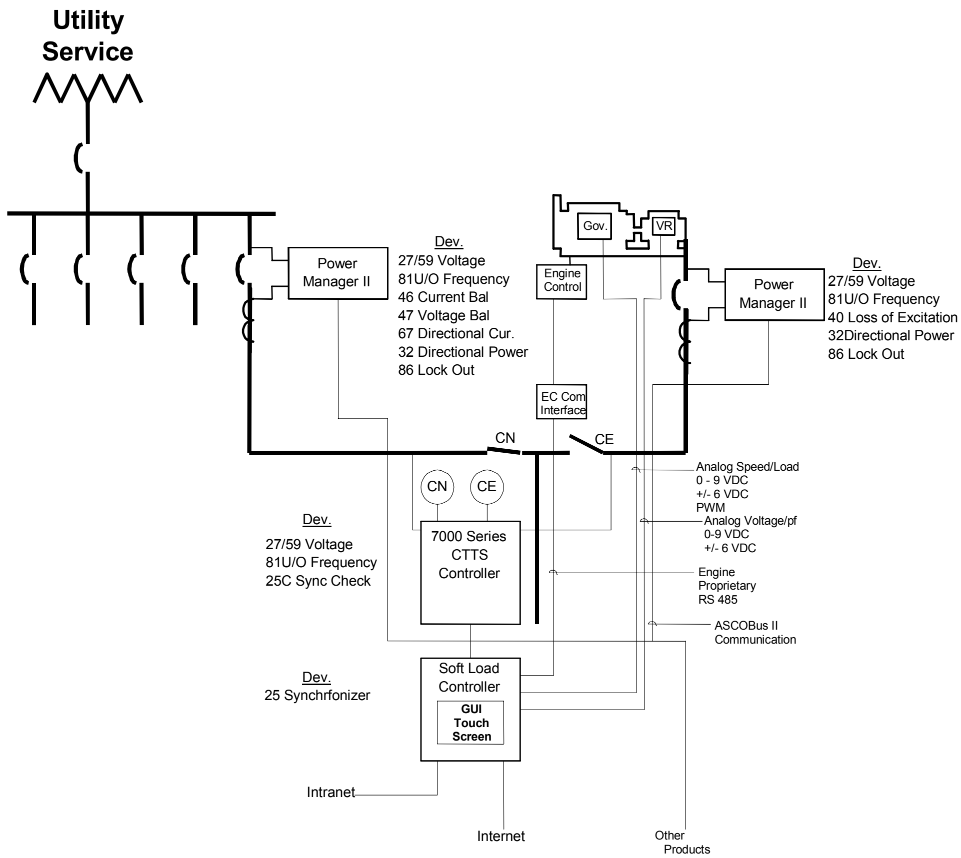


Figure 4-6. Global representation of the soft load transfer control and communications strategy

As Figure 4-6 indicates, the soft load controller can be accessed through the Internet. Obviously, the control will have password protection to prevent unauthorized access. It is useful to go through a typical operation. The operation begins with a remote terminal accessing the SLC to initiate a peaking operation. On initiation, the engine generator is started, and the SLC controls generator frequency and voltage to match the utility-derived source. The SLC then brings the generator into synchronism and initiates closure of the CE contacts. Once closed, the SLC causes the EG set to assume load. There are two modes of operation available. If islanding is selected, the EG set will take on load until the load remaining on the utility-derived service is reduced to a low preset value. At that point, CN will open, leaving the load on the EG set. If maintained parallel operation is selected, the EG set will take on load to some predetermined value. That value will not exceed the rating of the feeder circuit. However, it can be a value that could have a positive or negative power flow from the utility-derived feeder circuit. In the maintained parallel operating mode, EG set base loading, the EG set output increases to a value. If the load of the ATSE exceeds that value, then the utility-derived circuit will provide the additional power required by the load. If the load of the ATSE is less than that value, then the excess power will flow into the switchgear bus to which the utility-derived feeder is connected. Given that the load of the facility will exceed the EG set output, none of this excess power will flow into the grid, but it will serve to further reduce the facility demand on the grid. Thus the major advantage of the base load operation is revealed. Regardless of the real-time power demand of the ATSE load, a fixed, maximized facility demand reduction is made available for DR service. This operating mode has the maximum return on the incremental invested capital to achieve DR service. The incremental capital investment to achieve this operation can be in the $10,000 to $20,000 range.

Multiple Loads/Multiple Generators

An increasing need for power reliability has caused many facilities to install multiple EG sets to meet the expanded standby power needs of important loads. Figure 4-7 provides and illustrative example of such a facility. Obviously, power systems of this size provide major opportunities for peaking operation. In the system shown, the installed standby power infrastructure can be brought into operation for peaking either by transferring the loads to the on-site power bus or by adding a circuit for paralleling the on-site power bus with the utility-derived power bus. The advantage of parallel operation is that it provides for full use of the EG set capacity. The advantage of load transfer is that it minimizes the incremental investment to make the on-site power system available for peaking service. Load transfer peaking will require power managers with protective functions as previously discussed and an SLC.

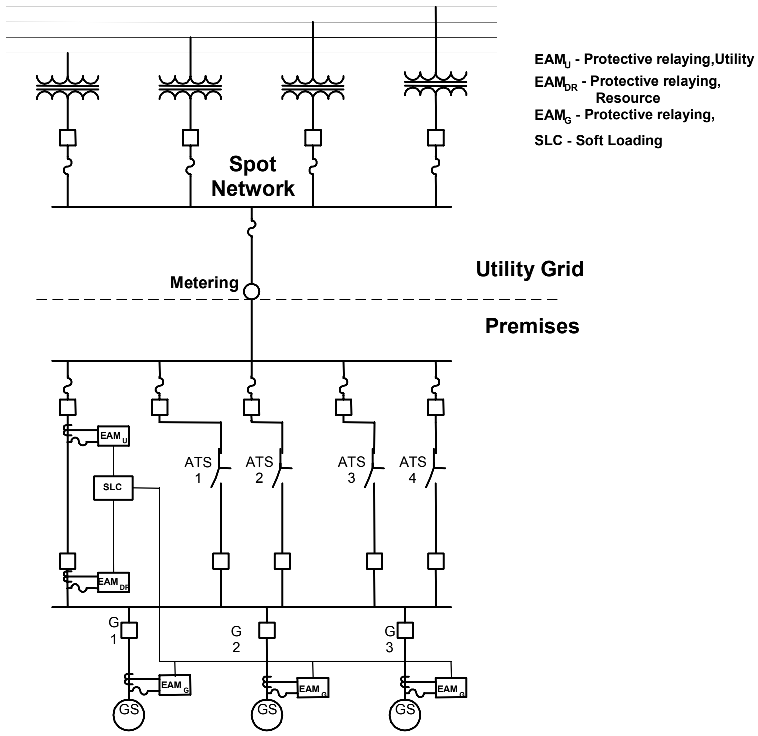


Figure 4-7. Multiple generators/multiple

Net Access

Referring back to Figure 4-6, note that the SLC has communications capability for intranet or Internet access. Where the SLC operates in a windows environment, there exists the opportunity to provide icon interface that makes operator use less foreboding. Such operating environments will typically provide adaptable formats. Communications are adaptable to a variety of data processing needs.

From the facility manager's point of view, the computer sitting on his desk can be booted with software that enables the communications in a Windows environment that allows him to tailor the performance to meet his needs. He may wish to be able to initiate the operation at will from his computer. In this case, using his password access, he could:

- Call on the generator to start, synchronize, parallel, and take on load
- Call on the generator to start and initiate load transfer
- Vary the load to meet the real-time need
- Structure an operating report
- Structure a real-time status report
- Archive operating data
- Accumulate trending reports
- Make the system available to an aggregator
- Toggle the operating scenario between islanding and base load.

Because most facility managers are already familiar with the Windows operating environment, tailoring the system configurations to site-specific conditions would be a relatively painless task. As experience grows, increased confidence will enable the manager to finesse the operation so to

achieve the optimum cost advantage of the system enhancements. The real issue is keeping the incremental cost of providing this flexibility low enough to provide an acceptable ROI.
Where on-site generation has been contracted to aggregators, they can directly access the facility in a similar manner through the Internet. Operating and reporting scenarios can be tailored to meet the needs. Orders of hierarchy can be established through password privileges to restrict the scope of flexibility at various levels. The facility manager can therefore restrict what the aggregator is permitted to do with the on-site generation system.

Summary

Modern on-site alternate power systems can be retrofitted and expanded to provide an alternative to the high cost of on-peak power. The costs for these enhancements have been significantly reduced as a result of the availability of cost-effective control strategies that take advantage of the World Wide Web communications environment. One can expect a reasonable ROI on the added infrastructure to take advantage of the sunk cost of installed alternate power systems.

4.2. "Associated Barriers to Distributed Generation," Robert D. Hartzel, PE, Cutler-Hammer Inc.

Introduction

Many issues affect the successful implementation of DG from both the customer and local utility perspective. The issues can be separated into four major categories:

- System coordination issues
- Present-day UIT systems
- Power quality concerns
- Utility/Regulating body paradigm shift.

System Coordination Issues

Many customers do not understand the importance of addressing system coordination issues before installing DG systems. If a system is not properly coordinated, it could result in equipment damage because of a severe fault current condition or unplanned outages because of improper system coordination.

Fault Current Considerations

Currently, each site must be analyzed by a qualified engineer to determine the magnitude of the worst-case fault current condition. The engineer must develop a one line diagram and write a sequence of operations on how the site's DG will function. The consultant must contact the local utility and request the available fault current contribution for the site in question. Finally, the engineer must use the fault current contributions from the utility and DG, one line diagram, and sequence of events to determine the interruption rating of the UIT equipment. Another consideration is when the DG is operated in parallel with the utility; this will increase the required interruption rating of UIT equipment. The magnitude of the effect will depend on the type of DG used.

Most consultants use the conservative approach and assume infinite bus conditions in conjunction with the impedance of the utility transformer to determine the maximum fault current available to the site from the utility source. This is a nice general approach; however, the equipment may be oversized and more expensive than what was really required.

This is time-consuming and adds cost to the implementation of DG. A possible alternative would be to conduct a comprehensive study of the U.S. electric power system to determine what the worst-case available currents are throughout the U.S. Then, analyze the data to determine if the data follows some type of probability distribution. The study may reveal that at 70% of the sites the equipment can be rated 65 kA. If the desire is to cover 90% of the sites, then the equipment may need to be rated 100 kA. And if a really conservative approach of 100% is used, then the equipment may need to be rated 200 kA. If this occurs, then analyze the data to see if there are any common parameters such as site voltage level, primary transformer size, primary transformer impedance, primary transformer voltage level, feeder size, or other. The study would need to be published and endorsed by all utilities so that all DG users throughout the United States can apply it.

Proper Coordination

In addition to determining the interruption rating of the UIT equipment, the consulting engineer must determine all the protective settings. This can be done by hand or by using available software packages. The engineer must determine the breaker trip unit settings, which include long, short, instantaneous, and ground fault settings. In addition, the protective relay trip settings must be determined for both the utility and the DG sources. The alarm settings must be determined so that the maintenance personnel have enough time to react to system disturbances before they become a trip condition. At this time, there is no means of short cutting this work.

Present-Day UIT System Issues

There are many advantages to the new universal interconnection systems currently in the market. Over the past few years, new embedded controllers have entered the market. These new controllers consolidated many functions, which required separate black boxes to perform discrete operations. Also, these separate boxes required many redundant point-to-point wiring terminations. Today, many of these connections have been replaced by integral logic in one controller. All external inputs are wired to the embedded controller with the rest of the “connections” for different functions performed in the software. This has increased the functionality of the new systems and reduced the chance for wiring errors, decreased testing and commissioning times, and reduced overall system costs. This has lead to lower installed costs, which in turn have lowered the breakeven point for implementation of DG at many more sites.

There are a few disadvantages to these new systems. They are more complex and require a higher-caliber startup engineer than the marketplace is accustomed to providing. Another issue is the varying degree of computer skills of the customer’s maintenance personnel. The smallest issue could result in a significant amount of time troubleshooting a trivial issue.

Although most customers have a desire to save money or explore the possibility of developing a second source of revenue, many do not understand DG. They are not knowledgeable about the different forms of DG, the associated cost of each, system design requirements, or who at the local utility should be contacted to determine all requirements and available programs.

A solution to these issues would be to increase plug-and-play capabilities. This would include developing menu-driven software for UIT systems that work with prime movers to allow quick selection of governors, voltage regulators, and prime movers. There should be defaults for all settable parameters that get the commissioning engineer close to stable system operation. Another alternative may be to add the governor and voltage regulator functions to the UIT embedded controller.

There needs to be a user-friendly, on-board software assistant that can review parameters and suggest appropriate changes for the commissioning engineer. In addition, the software must provide assistance to the site maintenance staff so that troubleshooting time can be minimized.

Educational material needs to be created that informs customers about DG with both positive and negative examples. The material needs to discuss what programs are available, different forms of peak shaving, associated payback analysis, questions to ask the local utility provider, and a review of the applications of various types of DG. After this information has been developed, a vehicle is required to disseminate the information to interested parties. It could be as simple as putting the information on every state Web site in multiple places or links to get interested customers to the right place.

Power Quality Concerns

There are two main issues of concern that affect electrical system power quality. They are harmonics and ferroresonance. Harmonics are becoming a more frequent issue with the increased use of inverter technology. Many harmonic issues are caused by the type of loads being served. One type of load that generates harmonics is variable speed drives. They can be purchased with different quality inverters (i.e. 6-, 12- or 18-pulse inverters) that produce different levels of harmonics.

Harmonics

An issue that is often overlooked by customers purchasing a variable speed drive is what the harmonics content is when connected to the utility, DG, or both (parallel operation). The higher the impedance of the source, the worse the effect of harmonics on the system.

For example, consider a customer site that contains a synchronous generator (15% impedance) as its DG source and a utility source (5% transformer). The site contains variable speed drives to operate pumps. The site can be operated on utility only, generator only, or both in parallel. On utility only, the total harmonic distortion (THD) is 2.3%. When on generator only, the THD is 5.7%, but with both in parallel, the source impedance is reduced to 3.75% and the THD is reduced to 1.75%.

The issue is that THD can cause the UIT system to misoperate if the levels are too severe, but implementation of DG is still positive from the utility perspective. If harmonics levels cause too much disturbance, they could lead to flicker problems at other customer sites. Many times flicker problems are related to large electrical loads being switched off and on quickly — such as electric arc furnaces.

Some possible solutions would be to develop customer incentive programs. These programs should encourage customers to use equipment that produces low harmonics. Again, educational literature is needed that explains the issues associated with harmonics and how source impedance affects THD levels.

Ferroresonance

There are two types of ferroresonance, and both produce sustained over voltages and core saturation. Saturation causes stray flux to be carried in the tank steel, which is a high-resistance short circuit by design. The losses from this condition could cause enough heat to raise the transformer oil to damaging levels. Ferronesonance can occur when a circuit with sufficient shunt capacitance energizes a lightly loaded transformer. Transformers at 14.4 kV and above have enough internal shunt capacitance to produce ferroresonance on their own. This issue will need to be examined if DG is to be used to serve peak power requirements or create intentional islands.

Utility/Regulating Body Paradigm Shift

Currently, there is no incentive for utilities to use DG to offset transmission and distribution costs. Because utilities have separated into distribution, transmission, and generation entities, their portfolios of operation are limited. For example, a distribution-only utility is not permitted to own or dispatch generation assets; however, it is obligated to serve its customers. So the utility will build transmission and distribution assets based on old paradigms and not consider using DG.

A possible solution to these issues would be to determine who should be given incentives to use DG. Maybe distribution-type utilities should be allowed to negotiate contracts with DG customers and dispatch their generation resources to defer construction of new transmission lines and minimize distribution cost. Maybe the value from this type of approach should be split between the utility and its customers. Regulations should be changed to allow the utilities to have higher returns if they actively use DG to control system costs.

Distribution Utility Issues

The present distribution system in the United States was not designed for bi-directional power flow. Thus, all of the stability and power flow models are based on having unidirectional power flow. The operating procedures for utilities require them to supply 100% of their load requirements with a safety margin equal to the largest generating resource, otherwise known as spinning reserve.

A possible solution would be to develop bi-directional distribution systems to allow power flow from DG customer sites. This could include installing additional synchronism check relays throughout the distribution system. New stability and power models are required that would use DG. The new distribution system may be more costly, but transmission line costs should decrease. Also, central plant cost should decrease along with overall energy cost. Finally, new tariff structures are needed to support DG versus building traditional transmission and distribution systems.

Another issue that will need addressed is the subject of spinning reserve. Most DG units take at least a few seconds to produce rated voltage and assume load. The user systems may need to incorporate a new technology, such as online energy storage devices, to ride through the periods when the DG is not producing power. Currently, there are systems available in the marketplace that could fill this need.

4.3. “Overview of Currently Available UIT Systems,” Paul E. Sheaffer, Resource Dynamics Corp.

The market for DG, or more broadly DER, continues to evolve. DER units are increasingly being evaluated by residential, commercial, and industrial users as solutions for their energy needs. In addition, the DER retrofit market shows great potential. With energy market restructuring, DER units can be interconnected with the grid, and standby capability can be expanded to provide peak shaving, interruptible rate, and export-to-utility functions.

Interconnecting DER to the grid can offer several benefits, which include:

- Giving the customer the flexibility to use the DER unit, the grid, or both
- Providing the customer flexibility to take advantage of special electric rate structures
- Taking advantage of the opportunity to export power to the Area EPS or to the power pool in deregulated markets
- Improving overall customer reliability by providing an alternative power supply option
- Obtaining backup power from the EPS in the event of a DER system outage, eliminating the need for complete system redundancy.

Realization of the associated benefits of DER depends on DER’s successful integration into the utility or Disco EPS distribution system operations without any negative effects on system reliability or safety.

The Need for a Universal Interconnection Technology

An interconnection system is the equipment that makes up the physical link between DER and the EPS, usually the local electric grid. The interconnection system is the means by which the DER unit electrically connects to the outside electrical power system and provides for monitoring, control, metering, and dispatch of the DER unit. In short, the interconnection devices perform the functions necessary to maintain the safety, power quality, and reliability of the EPS when DER are connected to it.

The complexity of the interconnection system depends on the level of interaction required among the DER, the customer loads, and the EPS. Typically, complete systems that allow a DER unit to parallel with the grid include the following components, which may or may not be modular:

- Exciter control system for the generators
- Synchronizer for the reliable transfer of power between the generators and the grid
- Automatic transfer switch control
- Import/export control
- Protective relay functions including over/under frequency and voltage at the interconnection points, directional real and reactive power flow, and phase-to-phase current balance
- Metering or net metering, depending on the tariff
- Remote communications capabilities to accommodate control from remote control centers (e.g., direct transfer trip, in some cases).

Different applications of DER require different levels of interconnection complexity, and most interconnection today is still performed on a site- and DER unit-specific basis. This greatly increases the cost compared with what it would be if the interconnection system were standardized. Beyond this, the lack of standardization of interconnection systems can be confusing for DER users and deter them from interconnecting with the grid.

For these reasons, there has been substantial interest recently in developing a UIT. Development of a UIT would define a standard architecture for functions to be included in the interconnection system. This standard architecture would allow both DER manufacturers and end-users to easily integrate their power systems with the Area EPS.

A UIT would include at least the following functions:

- Power conversion
- Power conditioning and quality
- Protection functions
- Synchronization
- DER (both generation and storage) and load controls
- Communications
- Metering
- Dispatch.

Other useful features could include the ability to provide ancillary services to the distribution system and the ability to communicate back to the utility the status of the distribution system.

Underlying development of a UIT are advances in interconnection components and in integrated power electronics. Electromechanical "discrete" relays — which dominated utility interconnection, protection, and coordination for years — are being supplanted by digitally based equipment, frequently with multifunction capability. Utilities themselves are gravitating toward digital, programmable relays, raising the issues of field calibration and certification. The rise of inverter technology as an alternative to rotating power conversion technology (i.e., induction and synchronous generators) has opened the door to integrated, inverter-based protective relaying.

In summary, a modular UIT will make DER installation cheaper, quicker, and more reliable and will also provide benefits to the distribution company.

Current UIT-Like Systems

Some third-party manufacturers are assembling systems of components to build complete interconnection systems that meet some of the UIT vision. There are two types of UIT-like systems currently in development:

- Traditional noninverter-based pre-engineered systems that allow for synchronization and parallel operation with the grid. Often, these assemblies are referred to as "switchgear," where all the necessary components are built into either panelboards, switchboards, or other suitable cabinets.
- Inverter-based UIT-like systems for prime movers with DC or high-frequency AC output (i.e., photovoltaic systems and fuel cells). These systems can also work with standard induction and synchronous generators.

These types of interconnection systems exist for both new DER and for the retrofit of existing DER units of various manufacturers.

Traditional Noninverter-Based Switchgear Pre-Engineered Systems

Noninverter-based interconnection systems use microprocessor-based digital controllers to synchronize and parallel DER unit operation with the grid. Often called “switchgear,” these systems are single pre-engineered structures that contain the many functions necessary for synchronization and parallel operation with the grid: operator interface, controls, protective relays, circuit breakers, and much more. Unlike inverters, these systems are generally used for DER units with more traditional AC output, such as reciprocating engines, and do not provide for power conversion with inverters.

One goal is to develop switchgear that can be universally applied. Several models on the market have achieved that goal. These units focus on simplified system installation and work with different styles or brands of generators. These UIT-like systems can be used for new DER units or to transform existing standby units to provide peak shaving, interruptible rate, and export-to-utility functions. Units are available from companies such as Detroit Diesel (SD-100), Shallbetter (DGX Switchgear), and Kohler (PD-100) as well as several others.

Several switchgear systems integrate components from multiple manufacturers. For example, the Shallbetter DGX Switchgear uses a digital controller from Woodward, protective relaying from Schweitzer (for utility relays) and Woodward (for genset relays), and monitoring systems and software from ZTR. Kohler’s PD-100 switchgear/paralleling switchgear system — which converts new or existing standby generators (from 20 kW to 2,000 kW) into peak shaving, prime power, or electricity exporting units — uses a controller from Encorp. A single line diagram of Kohler’s unit is shown in Figure 4-8.

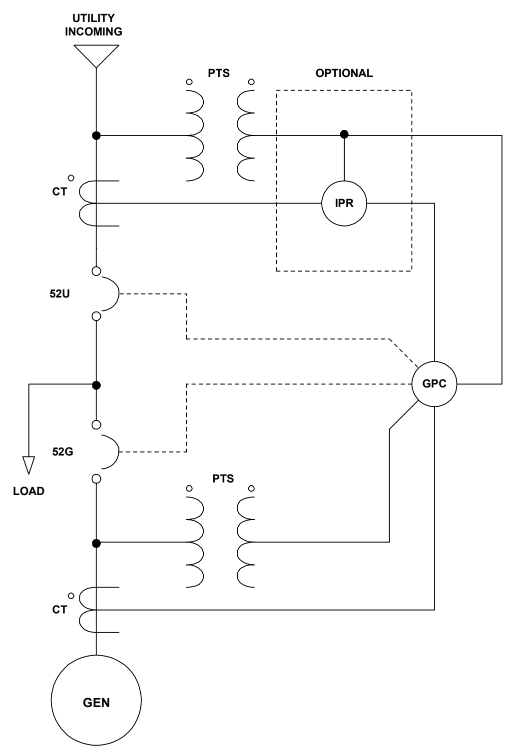


Figure 4-8. Switchgear single line diagram (Kohler PD-100)

Inverter-Based Systems

The inverter-based UIT-like systems are designed for use with prime movers with DC or high-frequency AC output (i.e., photovoltaics systems, wind, fuel cells, and microturbines). These technologies are expected to increase their share of total power produced in the United States and abroad, setting the stage for inverter-based UIT-like systems to interface DC power sources with the grid. Microturbines, which produce high-frequency AC, are well suited for use with inverter-based UITs because their rectified output (i.e., DC) can be directly fed to the inverter, which then converts it to 60-Hz AC.

DOE, through the Oak Ridge National Laboratory, recently published a white paper titled "White Paper on the Development of the Universal Inverter for Distributed Energy Resources." This paper outlines concepts and designs for the development of a universal inverter. The paper determines that for present-day inverters to meet the requirements of a UIT, several issues must be addressed. These include:

- Switching device ratings (and associated reliability issues)
- Transformers (and associated design limitations)
- Lower cost
- Control limitations
- Limitations on voltages that can be attained
- Creation of high levels of harmonic distortion.

In addition, DG inverters will be required to, at minimum, provide services such as voltage regulation, frequency regulation, and reactive power supply.

The DOE white paper focuses on the importance of modular inverter systems. Advanced Energy Systems offers two inverter-based interconnection systems: one for residential and small commercial power systems (photovoltaic and wind power) and the other for entry-level grid-tied, battery-less photovoltaic systems. These units meet UL 1741 and IEEE 929 requirements including anti-islanding and over/under frequency and voltage shift detection. Another currently available inverter-based UIT–like model is Ballard's EcoStar Power Converter, which is designed to operate with microturbines. A diagram showing the modular building blocks of an inverter-based UIT system is shown in Figure 4-9.

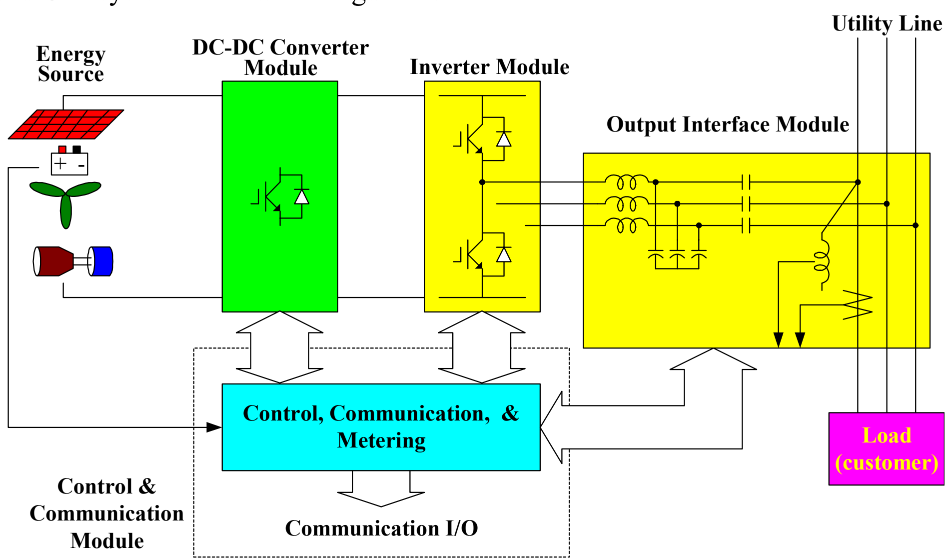


Figure 4-9. Universal inverter modular building blocks

Inverter systems also integrate components from multiple manufacturers. AstroPower SunChoice program offers two grid-tied PV systems: the SunLine™ system and the SunUPS™, which includes emergency power (battery backup) capabilities. These systems incorporate inverters produced by AEI (GC-1000 and GC-3000 models), Xantrex (XR1500 and XR2500), and SMA (sunny boy SWR1800 and SWR 2500).

In the future, inverter-based interconnection systems may be applied to standard reciprocating engine gensets. Benefits include higher efficiency and lower emissions at part load. Honda currently manufacturers a 3,000-W genset, whose generator produces 200 V at 14 Hz to 17 Hz, which is converted to 12 V DC and then inverted to 50 Hz or 60 Hz AC. Honda claims a higher power quality than standard gensets.

Current Products

The table below lists some of the UIT-like systems currently on the market. These systems will need time to truly obtain the goal of "universal" status; meanwhile, they highlight market developments.

Currently Available UIT-Like Systems

Company	Unit	Inverter	Non-Inverter	Electrical Specification
Advanced Energy Systems	*MM-5000 Grid-Connected MultiMode Power Conversion System*	X		5 kVA
	GC-1000 1kW Grid-Connected Photovoltaic Inverter	X		1 kVA
AstroPower	*SunChoice Program*	X		8.5 kVA
Ballard	*EcoStar Power Converter*	X		Up to 110 kVA
Cummins Power Generation	*PowerCommand Digital Paralleling Equipment*		X	Up to 2,500 kVA
Detroit Diesel	Spectrum SD-100		X	Up to 2,400 kVA
Encorp	enpower-GPC powered "paralleling switchgear"		X	800-5000 amp
Fire Wind and Rain Technologies, LLC	Power Streak Inverter	X		5kVA
Kohler	*PD-100 Switchgear*		X	Up to 2,500 kVA
Thomson Technology	*Distributed Generation Switchgear System/ GCS 2000-DG System*		X	Up to 4,000 amp
Vanner Inc.	*RE Series Inverters*	X		5.6 kVA
Xantrex	*Grid Tie Inverters*	X		Up to 125 kVA
Shallbetter	*DGX Switchgear*		X	Up to 4000 amp

Details of existing manufacturer product offerings, based on manufacturer-developed product literature, are now provided.

Advanced Energy Systems. Advanced Energy Systems has two grid-connected inverter-based systems. The MM-5000 Grid-Connected MultiMode Power Conversion System is a two-stage, DC-to-AC grid-tied inverter designed for residential and small commercial power systems (PV and wind power). It operates in stand-alone, grid-parallel, backup generator, and multi-unit modes with simplified programming and data retrieval, flexible operating modes, and intelligent user and wiring interfaces. It offers a fully integrated, single-box solution, including a charge controller and all switchgear, a single reprogrammable microcontroller, and complete system control. Anti-islanding technology is available for operation in grid-parallel mode, and an input ground fault protection circuit provides improved operating safety.

The GC-1000 1-kW Grid-Connected Photovoltaic Inverter is for entry-level grid-tied, battery-less photovoltaic systems. The inverter includes a string combiner, DC and AC disconnects, and ground fault interrupt protection. An optional interactive data monitor is also available. This system meets UL 1741 and IEEE 929 requirements including anti-islanding and over/under frequency and voltage shift detection.

AstroPower. AstroPower's SunChoice program offers two grid-tie PV systems: the SunLine™ system and the SunUPS™, which includes emergency power (battery backup) capabilities. These systems incorporate inverters produced by AEI (GC-1000 and GC-3000 models), Xantrex (XR1500 and XR2500), and SMA (sunny boy SWR1800 and SWR 2500).

Ballard. Ballard's EcoStar Power Converter is designed to operate with microturbines, although subsequent units will be targeted at internal combustion engines, PV systems, fuel cells, wind turbines, super capacitors, and flywheels. The converter provides "electric grid compatibility," anti-islanding functions, parallel operation, and communication ports and protocols for units up to 110 kVA.

Cummins Power Generation. The Cummins PowerCommand Digital Paralleling Equipment includes all monitoring, protection, governing, and voltage regulation as well as all paralleling control functions including synchronizing, load sharing, and paralleling protection plus utility paralleling functions such as import/export control and VAR and power factor control. Their PowerCommand Network is a Windows®-based, distributed system for local or remote monitoring and control, real-time data collection, retention, and report generation on generator sets, transfer switches, paralleling controls, switchgear, and other related power generation and distribution equipment. The combined system interfaces with all leading building management systems and automation packages.

Detroit Diesel. The Detroit Diesel Spectrum SD-100 works with new or existing gensets in several modes including standby power, peak shaving, interruptible rate, and export-to-utility modes. The system includes operator interface, controls, protective relay, a circuit breaker (800 A to 4,000 A) for paralleling, and monitoring functions for electric systems up to 600 VAC at 60 Hz.

Encorp. The Encorp enpower-GPC "paralleling switchgear" includes control modules, protective relays, and network communications capabilities in a single, microprocessor-based "gold box." The system parallels one genset with the utility in base-load, peak-shaving, import/export, or zero-power-transfer mode and can be used for new gensets or for retrofit options. The enpower-GPC supports both the Modbus® and LONWORKS® communication protocols.

Fire Wind and Rain Technologies, LLC. This company's Power Streak Inverter can be used for grid tie or stand-alone application. The Power Streak 4K is the first member of the Power Streak family of inverters/battery chargers based on a versatile modular inverter subsystem. It contains everything necessary for use including the inverter, weatherproof enclosure, DC and AC disconnects, isolated computer interface, remotable liquid crystal display, generator control modes, and more. It is also UL 1741-/IEEE 519-compliant. The Power Streak is available with several input and output options including 48 V or 120 V DC inputs and 120 V or 240 V outputs.

Kohler. The PD-100 Switchgear/Paralleling Switchgear system is used to turn new or existing standby generators (from 20 kW to 2,000 kW) into peak shaving, primary power, or electricity exporting tools. The system includes a circuit breaker (800 A to 4,000 A), touch screen monitoring, control functions (the controller is manufactured by Encorp), protective relaying, and communications for systems up to 600 VAC at 60 Hz.

Shallbetter. Shallbetter Inc. produces the DGX Switchgear, which can be used for a genset paralleled to the utility, upgrading no-automatic switchgear, or for a genset retrofit. The system combines components from several manufacturers: a digital controller (Woodward EGCP-2), protective relaying (utility: Schweitzer, genset: Woodward EGCp-2 integrated feature), and monitoring via a ZTR-Lynx monitoring and supervisory control system. The switchgear is used for units up to 15 kV.

Thomson Technology. Thomson Technology Inc.'s Distributed Generation Switchgear System/GCS 2000-DG System is used for synchronizing single or multiple generators to the utility grid. The system incorporates control logic and software programming for automatic synchronizing, soft load transfer, and automatic load (kilowatt) and VAR/PF control. It can work with a variety of industry standard communications for remote monitoring, control, and data logging and can be used with either new systems or retrofits.

Vanner Inc. Vanner makes a series of inverters, including the RE Series, that accepts grid or generator input. The RE Series is designed specifically for alternative energy applications and includes multiple functions, including transfer switch and automatic generator control capabilities. The inverter has a 4,500-W continuous output and is programmable with the inverter/charger remote control.

Xantrex Technology Inc. Xantrex manufactures utility interactive, three-phase inverters for solar arrays, with models ranging from 5 kW to 100 kW. Multiple inverters may be paralleled for larger power installations. Functions such as over- and under-voltage and frequency protection, anti-islanding protection, automatic operation including start-up, shutdown, self-diagnosis, and fault detection are included. The grid tie system consists of a solar array and the grid tie inverter, which includes all components necessary to make a grid connect system installation. The Trace™ ST Series inverters include the balance of system components for ease of installation.

Built-In Systems

Many DER manufacturers have been either building in, or offering as an option, some of the key interconnection equipment components as part of their DER genset offerings. Some of these units, especially those incorporated into microturbines and fuel cells, have many of the same functionalities as a UIT.

In an effort to streamline the interconnection approval process, the California Energy Commission has established type testing and production testing requirements for equipment under its Rule 21 program. Systems that meet these requirements are considered to be certified equipment for purposes of interconnection with the distribution system. Rule 21 certification may apply to either a pre-packaged system or an assembly of components that address the necessary functions. Thus far, DER manufacturer systems are the only systems to be certified, though it seems likely that UITs could benefit from this process as well.

Plug Power's Model SU1PCM-059622 5-kW stationary fuel cell system was recently certified to comply with the Rule 21 requirements. Capstone's Model 330, 30-kW microturbine generator and Model 60, 60-kW microturbine have also been certified to Rule 21. These systems, like a UIT, contain all the components necessary for interconnection.

Future UIT Functions and Features

An issue for any UIT is its ability to provide certain functions and features. As a starting point, any UIT must provide safe interconnection with the EPS including all the necessary functions previously mentioned (power conversion, power conditioning and quality, protection functions, synchronization, DER and load controls, communications, metering, dispatch, ancillary services, and communication of the status of the distribution system) — without harming grid reliability or power quality.

Beyond these functions, there are a number of features that should exist in a UIT. Some features are listed below:

- Adaptability
  The ease with which a system satisfies differing system constraints and user needs.

- Affordability
  To have a cost that is bearable. For a UIT system, the cost of the interconnection component is a small part of the overall installed DER system cost.

- Availability
  The degree to which a system is operational and accessible when required for use.

- Compatibility
  The ability of two or more systems or components to jointly perform their required functions while sharing the same hardware or software environment.

- Dependability
  That property of a system such that reliance can justifiably be placed on the service it delivers.

- Extendibility or Expandability
  The ease with which a system or component can be modified to increase its storage or functional capacity.

- Evolvability
  The ease with which a system or component can be modified to take advantage of new (internal) software or hardware technologies.

- Flexibility
  The ease with which a system or component can be modified for use in applications or environments other than those for which it was specifically designed. For interconnection systems, the ability to adapt to:

  - New types of DG prime movers,
  - Emerging storage platforms,
  - New applications (e.g., ancillary services),
  - Diverse distribution systems,
  - New communications protocols.

- Generality
  The degree to which a system or component performs a broad range of functions.

- Interoperability
  A system than can exchange information with and use information from other systems.

- Modularity
  A modular interconnection architecture divides the interconnection system into discrete components (building blocks), each performing standard functions such as the following:

  - DER control
  - Power conversion
  - Voltage regulation
  - Power quality
  - Protection
  - Synchronization
  - Communications/control with load
  - Metering
  - Dispatch
  - Area EPS communications and support.

  The definitions of the modules should be generic enough to apply to both inverter and noninverter systems so that they have common building blocks. Not all interconnection systems will require all blocks.

- Maintainability
  The ability of a system, under stated conditions of use, to be retained in, or restored to, a state in which it can perform a required function.

- Modifiability
  The degree to which a system or component facilitates the incorporation of changes, once the nature of the desired change has been determined.

- Portability
  The ease with which a system or component can be transferred from one hardware or software environment to another.

- Reliability
  The ability of a system to perform a required function under stated conditions for a stated period of time.

- Scalability
  The ability to incrementally add functionality to a system without replacing it completely. Scalability means that an interconnection system designed for one application (e.g., peak shaving) may be "scaled up" by adding additional modules for a more complex application (e.g., utility dispatch).

- Survivability
  The degree to which essential functions are still available even though some part of the system is down.

- Vulnerability
  The degree to which a software system or component is open to unauthorized access, change, or disclosure of information and is susceptible to interference or disruption of system services.

One goal of the UIT Workshop is to review how well existing technology provides these functions and features and where there are gaps in existing technology. In answering this, there may well be differences in the new generator and retrofit markets.

4.4. Participant Discussion

Utility approval plays a determining role in the success of DER interconnection with the EPS. A series of factors have combined to make utilities, in many instances, uncomfortable with or resistant to DER interconnection. Addressing utility concerns will be an important part of UIT development.

Utility Adoption of DER

How can we design a UIT system so that utilities embrace DER?

Utility needs will play a role in the development of the UIT. Several functionalities were discussed that could be included in the UIT to make it and DER more attractive to utilities. First among these was universal testability. The ability to provide ancillary services, dispatchability, and aggregatability were listed as additional functions of import.

Standardized tests and connections are necessary for utilities to feel comfortable with DER. Some suggestions were labels on the unit for utility workers, standardized plugs for utility testing of the DER units, and standardized lists of tests for which the DER units must be able to provide information. It was commented that Capstone has just placed an item in its microturbine that the utility can plug into and immediately test unit relays. This was done in response to utility desires to be able to test the unit itself.

Standardizing communication interfaces can be complicated by a utility's desire to retain its own SCADA system. Therefore, any conversation about interface standardization must include input from utilities as to their interest in and willingness to use it. Participants noted an often unanticipated result of DER interconnection. DER units, supplied with testing and monitoring systems, are often able to highlight and report problems with or errors on the grid. Whether this detection is a positive or a negative from a utility perspective differs greatly depending on circumstances.

5. Session 4: Technology Challenges and R&D Solutions

5.1. "Universal Interconnection Technology," Dr. Robert Wills, PE, Advanced Energy Inc.

Introduction

It is important to understand *why* we want DER so that we can best establish *how* to implement them.

In 1973, E. F. Schumacher said in his classic book, *Small is Beautiful*:

> We need methods and equipment which are:
>
> - Cheap enough so that they are accessible to virtually everyone;
> - Suitable for small scale application; and
> - Compatible with man's need for creativity.

Small is Beautiful is the underlying philosophy behind DER. Thirty years later, however, there are additional reasons for adopting this technology.

The foremost of these now is security — which may be divided in to three areas: power reliability, power quality, and immunity from attack. The National Research Council in a recent report to Congress and the Department of Homeland Security recommended that we "develop, test, and implement an intelligent, adaptive electric-power grid."

> Recommendation 16: Technology should be developed for an intelligent, adaptive power grid that combines a threat-warning system with a distributed-intelligent-agent system. This grid would be able to rapidly respond with graceful system failure and rapid power recovery. It would make use of adaptive islanding—a concept employing fast-acting sensors and controls to "island" parts of the grid as the rest comes down—and technologies such as storage units positioned at key points to minimize damage during shutdown. The system would need to be able to differentiate between a single component failure and the kind of concurrent or closely coupled serial failures at several key nodes that would indicate the onset of a concerted attack.

The following was reported in the *LA Times* and on CBS News:

> *— 1 July 2002*
> *Attacks on Power Companies Growing*
> *Power companies are increasingly being targeted by hackers, according to data gathered by RipTech. FBI spokespersons expressed concern.*

Another reason is the environment. We know that atmospheric pollution from power plants is contributing to global warming. New technologies such as fuel cells offer much cleaner ways to generate electricity. Schumacher said:

> Small scale operations, no matter how numerous, are always less likely to be harmful to the natural environment than large-scale ones, simply because their individual force is small in relation to the recuperative forces of nature.

Further, we are using our natural capital (i.e., coal and oil) instead of changing to sustainable energy systems. Again, from *Small is Beautiful*:

> It is clear that the "rich" are in the process of stripping the world of its once-for-all endowment of relatively cheap and simple fuels.

DER also promise lower energy costs by having lower initial design costs, shorter time to market, standardized components, higher efficiencies (which still need to be demonstrated for most technologies), heat recovery (also known as combined heat and power, or CHP), storage (for distributed energy storage devices), and lower distribution losses (as electricity is generated near its place of use).

The main impediments to the wide-scale implementation of DER have been cost, immature technology, and safety concerns:

- Will a DER device energize a section of the grid (i.e., form an island)?
- Will it damage utility or consumer equipment?
- Can it disrupt power quality or reliability?

In summary, to make DER fully viable, we need to make these devices:

- Secure (providing reliable, high quality power and immunity from attack)
- Flexible (capable of feeding the grid and operating in intentional islands)
- Efficient and Cost-effective
- Renewable and Sustainable
- Safe

Interconnection Technology

In the technology area, many issues have been solved:

- IEEE 1547 will become a national standard for characteristics such as voltage and frequency trip setpoints and islanding performance
- Current-controlled inverters are well understood; the quality of the power generated by DER systems is satisfactory.
- Adequate anti-island techniques have been developed.

Other issues are still open:

- Multi-inverter islanding has not been addressed.
- Methods of controlling microgrid and intentional islands need to be developed and standardized.
- Well-defined procedures are needed for testing to minimize time to market and costs and to ensure reliable results.
- The possibility of DC being fed onto the grid needs to be addressed.
- There is a need to certify controllers, control schemes, and controller code rather than individual inverter models (we believe that this is a key to universal interconnection).

Finally, there are myths that need to be dispelled. Examples are:

- Voltage and frequency protective relaying alone can provide reliable anti-islanding protection. Protective relays are still considered acceptable by many utilities.
- UL 1741 island tests are sufficient to ensure multi-inverter protection.
- Induction generators cannot island.
- Islanding is unlikely to occur. This is true for properly designed inverters — but islanding is actually very likely to occur if anti-islanding schemes are not implemented well.
- Line workers are endangered by islanding. Standard procedures, which are carefully followed, require disconnection, test, and grounding of equipment before any work starts.

Islanding

The basic theories of island prevention are now well understood. We believe that the problem is essentially solved.

Advanced Energy introduced the ideas that now are accepted as best practice in the United States (real and reactive power feedback schemes) and has been granted a broad patent on these concepts. The patent covers feedback and acceleration methods that are also known as the Sandia Voltage and Sandia Frequency Shift techniques (SVS and SFS).

There is still, however, work to be done. We need to prove the viability of island prevention techniques at high penetration levels, we need to model stability in the wide-area grid as penetration increases, and we need to model and test multi-inverter systems and various methods operating together.

There is also a need for standardized test methods that clearly identify test setups and procedures. An example of this is the current question as to whether Sandia's test equipment (with iron-cored inductors) differs significantly from UL's test setup (with more linear but higher-loss air-cored inductors). Finally, there is a question of whether we should test with rotating machine loads even though there is strong evidence that induction motors will not support islands any more than an equivalent compensated RLC circuit.

Anti-Islanding Primer

The following is a brief summary of the various methods that are used for island prevention.

Passive Trips (Voltage and Frequency). If the grid voltage or frequency goes outside set limits, the inverter stops exporting. This is sufficient to prevent islands where there is real or reactive load mismatch. As the load will respond to Ohm's Law (voltage = current x impedance), the allowable limits translate directly to the possible islanding load range.

Phase Jump Detection. Phase jump detection causes a shutdown if a sudden change in phase of the grid voltage waveform is seen. It was used successfully in early U.S. inverters such as the APC Sunsine. It suffers from two problems: sudden voltage phase changes can occur on a normal grid if low power factor loads such as induction motors come on line (leading to false trips), and a well matched load will not create a phase jump upon loss of grid (leading to a non-detect zone).

Harmonic Monitoring. This technique was popular for a while, but relying on either ambient grid harmonics or high-frequency signals generated by the inverter is subject to wide variability, especially if other noise sources or harmonic traps such as power factor correcting capacitors are present.

Impedance Measurement/Power Shifting. Impedance measurement and power shifting are essentially the same. If we change the output current and observe the resulting voltage change, we are measuring impedance. The problem with simple impedance measurement is that if multiple inverters are used, and the power shifts are not synchronized, then the voltage change in response to a current change will be diluted by the number of inverters online. If they are synchronized, then flicker problems are likely. It is generally accepted that simple power shifting techniques are not adequate in multi-inverter installations. The German ENS system is an impedance measurement system.

Frequency Bias. These methods generate a current waveform that is slightly higher or slightly lower in frequency than the observed voltage waveform frequency. They fail at high Qs where the frequency bias is overcome by the load phase characteristic and also require a decision whether to always go up or to go down (which may be conflicting in a multi-inverter situation).

Real Power Feedback. This method responds to small changes in grid voltage by making a change in output current that would result in an even bigger change in voltage, should an island exist. This is also known as the Sandia Voltage Shift method. After a few cycles, the inverter stops with an upper or lower voltage trip. When carefully implemented, this technique can provide reliable island protection in both the single and multi-inverter cases.

Reactive Power Feedback. Reactive power feedback is similar to real power feedback. The reactive power output of the inverter (or phase or shape of the output current waveform) is changed in response to an observed change in the operating frequency of the inverter. As the inverter load in an island situation can be modeled as a parallel RLC circuit, changing the inverter's reactive power output is the same as adding inductance or capacitance to the RLC tuned circuit, and thus changing its resonant frequency. After a few cycles, the inverter stops with an upper or lower frequency trip. This technique is also known as the Sandia Frequency Shift method. It can be combined with the real power feedback method and will provide reliable island protection in both the single and multi-inverter cases.

Direction & Acceleration. Two other concepts were introduced in our patent. First, the direction of the power or frequency response should be in the same direction as the observed change on the grid (and so in the same direction as other inverters). This overcomes the problem of deciding whether to bias up or down in frequency or power. We call this "following the herd." The second concept is acceleration. If the voltage or frequency continues to change in the same direction, the magnitude of the response is increased exponentially each time. This results in faster trip times, lower initial response values, and undetectable flicker levels.

Islanding — Known Problems

Nondetect Zones. Professor Michael Ropp's work in modeling frequency bias schemes showed that these, and most other nonfeedback techniques, suffer from nondetect zones (NDZ) in the load impedance plane. For example, power shifting will not detect inside the allowable grid voltage limits, and frequency bias will not detect if the load Q exceeds the slope of the inverter phase/frequency characteristic. Recently, we have discovered other nondetect areas related to thresholds and measurement and output resolution.

Flicker. Any method that causes changes in inverter output power may result in flicker problems. The change in output must be carefully balanced with respect to flicker and anti-island sensitivity. The voltage and frequency feedback methods do not have flicker problems if acceleration is used.

Typical output current variations are of the order of 0.5%, which is the output control resolution of the inverter.

Dilution of Power Shifting Methods. This is discussed above. The voltage change in response to a current change will be diluted by the number of inverters online.

Thresholds. Some island protection techniques rely on a measured value exceeding a fixed threshold to initiate a power or frequency change. This can lead to nondetection if the noise level in the island is lower than the threshold. Techniques that rely on fixed thresholds are best avoided.

Measurement Resolution. Another nondetect problem can come from quantization of input measurements. For example, a voltage feedback scheme that measures grid voltage with 1 V rms resolution may not see any changes in voltage once an island occurs and will not initiate power output changes.

Output Quantization. If a 1-kW inverter can only control its output in 5% steps and a 1% change in input voltage is seen, the required output change may be calculated as 2%, which is less than the output step size — power feedback will start only if a voltage change of 2.5% is seen. This is another form of threshold NDZ.

Incompatibility of Different Methods. The largest unknown in islanding is how different methods will interact. For example, how will a voltage feedback scheme work with a power-shifting scheme? Much depends on the number and size of inverters of each type.

Some combinations are clearly incompatible — a frequency-shifting scheme that pushes up combined with an inverter (or perhaps a motor load) that is pulling down, for example.

Islanding Conclusions

We believe that our real and reactive power feedback methods are presently the best possible techniques for island prevention.

Because of the potential for incompatibility between different methods, we believe that a standard anti-islanding method, not a performance test, should be adopted. A standard method would also lend itself to certified inverter controllers.

Finally, we must base future work on theory, not on experimentation. We should use understanding and accurate computer models to establish the viability and reliability of our islanding protection schemes.

DC Injection

Many inverter designs can inject DC onto the line. For example, a half-bridge inverter such as the older Omnion design with a shorted IGBT (and probably also a control system failure that allows the AC contactor to close) could connect 400 V DC from a PV array directly to a 120 V distribution line. There may be industrial or commercial equipment that could create the same hazard on multiphase systems — for example, rectifiers, motor drives, and welders. Incorrect installation could create this hazard even with a transformer-isolated inverter if a DC input wire came loose and shorted to the output.

High-voltage DC could be very hazardous to a line worker who is only equipped with AC measuring equipment. Because of this, there is an urgent need to alter utility test procedures. A compensating factor is that this problem could only occur at the level at which the inverter is connected (typically the distribution transformer secondary), and so precautions would not be needed at the medium voltage distribution level.

Some utilities are questioning non-transformer-isolated designs, but this is more from a concern of saturating distribution transformers than of creating a safety hazard. There is a need to distinguish between high-frequency isolation transformers in DC-link inverters (that still have high voltage DC outputs) and low-frequency isolation transformers.

We need to establish minimum monitoring and protection requirements (such as checking for DC voltage components on the inverter output) for inverters that do not use low-frequency transformers.

Microgrids and Intentional Islands

The National Research Council recommended that we develop an intelligent, adaptive electric-power grid. This means that DER devices will not only need to export power to the normal grid, but they must also be able to support an intentional island.

We need to agree on how devices will work together via communications and their electrical interface. We must allow for steady state, transient, and fault conditions and also for nonunity power factor and high harmonic loads.

We must also develop schemes for dispatching devices both in minigrid and normal grid-connected modes. For example, in a minigrid, we should run just enough generation to satisfy the load and recharge energy storage.

AEI has been working on these and related problems for three years with the Sandia Energy Storage group.

Certified Controllers

Presently, the cost of listing an inverter with Underwriters Laboratories is very high and is increasing (it is typically $50,000 to $100,000 per inverter). Much of this testing is to verify the anti-islanding performance of the inverter. Tests are required at 25%, 50%, and 100% of inverter rating with high Q RLC matched load (100% resistive, 250% inductive and capacitive).

This testing could be eliminated if the anti-islanding method were completely understood and if the behavior of the inverter controller were fully tested and certified.

From both the manufacturer’s and the utility’s point of view, it would be far preferable to have one certified controller than 10 inverter models.

The functions tested in a certified controller would include:

- Under and over voltage and frequency trips
- Active anti-islanding scheme
- Power quality (to be retested on each inverter version)
- Intentional island support mode
- Mode transitions

- Safety shutdown behavior
- Watchdog functionality
- Nonvolatile set points
- Calibration accuracy and reliability
- Dual redundant grid voltage sensing
- Communications protocol compliance.

We believe that this is a major step on the path to universal interconnection technology.

Communications

DER communications are required for performance monitoring, remote diagnostics, and control/dispatch functions. Even though a well-designed DER system should be able to operate autonomously, remote communication is necessary to allow the full benefit of DER (especially dispatch based on real-time pricing) and to minimize field service costs.

The IEEE recently approved the formation of a working group for P1614, Draft Guide for Monitoring, Information Exchange, and Control of Distributed Resources Interconnected with Electric Power Systems. This working group will be the focus for DER communications work.

Key areas in this work are:

- Protocol definitions
  It is likely that multiple protocols will be supported, including existing utility SCADA protocols. An XML protocol is also likely to be supported.
- Object models
  data description models for inverters and generation and storage devices
- Security
  data encryption standards, key management, authentication
- Threat analysis and warning
  as identified in the National Research Council report.

As communications controllers must be very low cost, especially for the smaller DER systems, an important area that requires development is encrypted protocols that are adequate but simple enough to be implemented on low-end microprocessors. Software to implement standard Internet (TCP/IP) communications on low-cost microprocessors is readily available, but cryptographic security protocols such as the Secure Sockets Layer (SSL) are presently not.

Conclusions

The key areas that we have identified for research toward a UIT are:

- A standard anti-islanding method that is proved in the multi-inverter case
- Control schemes for microgrids and intentional islands
- Certified controllers
- Test procedures
- Communications protocols and object models
- Cryptographic techniques such as SSL for use in microcontroller-based DER communications devices.

“There is a wisdom in smallness if only on account of the smallness and patchiness of human knowledge, which relies on experiment far more than on understanding.” — E.F. Schumacher

5.2. Participant Discussion

The general reaction from industry was that UIT is needed for and would benefit the adoption of DER within the electric infrastructure. Further benefits are to be gained through the development of a modular UIT. Understanding the modular concept and how it might be used in designing a UIT is an important step toward achieving these benefits.

A group discussion was initiated to address these issues, and the following questions were presented:

- What benefits might accrue from a modular design?
- Does a modular design produce benefits when different companies work on components of a UIT?
- How might the basic functions of a UIT be organized into a block diagram (modules)?
- Regarding the list of UIT functions, would there be any differences by size?

5.2.1. UIT Modularity

What benefits might accrue from a modular design?

The list below was generated by participant comments.

- Modularity is good if it is done right. It is important to look forward.
- For a manufacturer, modularity is beneficial from both cost and niche marketing perspectives.
- With modularity, customers do not have to pay for a multi-megawatt machine's worth of components for a 100-kW machine. Using the computer analogy, it is like not having to buy a super high-powered computer if all you want to do is use a word processing program.
- Modularity allows selectability based on size and other system characteristics. Modularity allows mass customization.
- It is important to know what customers: (1) need, (2) want, and (3) would like to have in determining the progress of the modular design and of components over time.
- Modularity enables other abilities.
- Software modularity keeps costs down for smaller units, while the software-based components keep costs down for manufacturers.
- Modularity has costs, as it can limit the supplier finding the most efficient way to solve a problem. The process must look at company core competencies and use modularity only in interfaces with areas outside this core.
- Contractors want a package that works, as they have little interest in doing detailed engineering.
- Modularity may work when the market is young, but, after building a certain number of units, will companies just start producing a set product to target to market niches with options included automatically?
- Modularity's value depends on the expected life cycle of the product. If the life span is short, then you must be able to easily upgrade it. In this instance, modularity is important. However, for high capital products expected to last for the life of the facility, modularity is not important because the system is only required to interface with the outside world.
- Now that software is so important, we must be sure to look at software modularity.

5.2.2. Benefits to Multisource UIT Component Manufacturing

Does a modular design produce benefits when different companies work on components of a UIT?

It was noted that modularity drives lower costs and addresses customer concerns about being tied to one supplier. It was agreed that there are significant benefits to be had for businesses from building a modular UIT.

5.2.3. UIT Block Diagrams

How might the basic functions of a UIT be organized into a block diagram (modules)?

A series of example module block diagrams were presented and discussed, including a diagram presented by Dr. Sam Ye of GE Global Research Center, a diagram from Resource Dynamics Corp., and a diagram developed by Joe Koepfinger of Koepfinger Consulting. Initial group comments included:

- Too little focus is placed on synchronous generators in favor of inverter-based systems.
- Diagrams should be technology-neutral.

As part of the discussion, the group determined that although a comprehensive diagram must still be developed, the diagrams presented provide a starting point for discussions of modularity, functions, and interfaces. The group agreed that the yet-to-be-developed UIT block diagram will likely include:

- Two paths (or subsystems): (1) power subsystem or path and (2) logic and control path — with communications and data links between the two paths
- Six to seven interface points
- A controller that has a standardized interface with the other components of the interconnection system, so that different manufacturers' controllers would be interchangeable, providing flexibility, expandability, and second sourcing.

Of particular interest from the GE diagram was its representation of standardized/normalized interfaces (see Figure 5-1). This diagram also carried the "two basic modules" concept, naming these the intelligent electronic device (IED) and the power-carrying device (PCD).

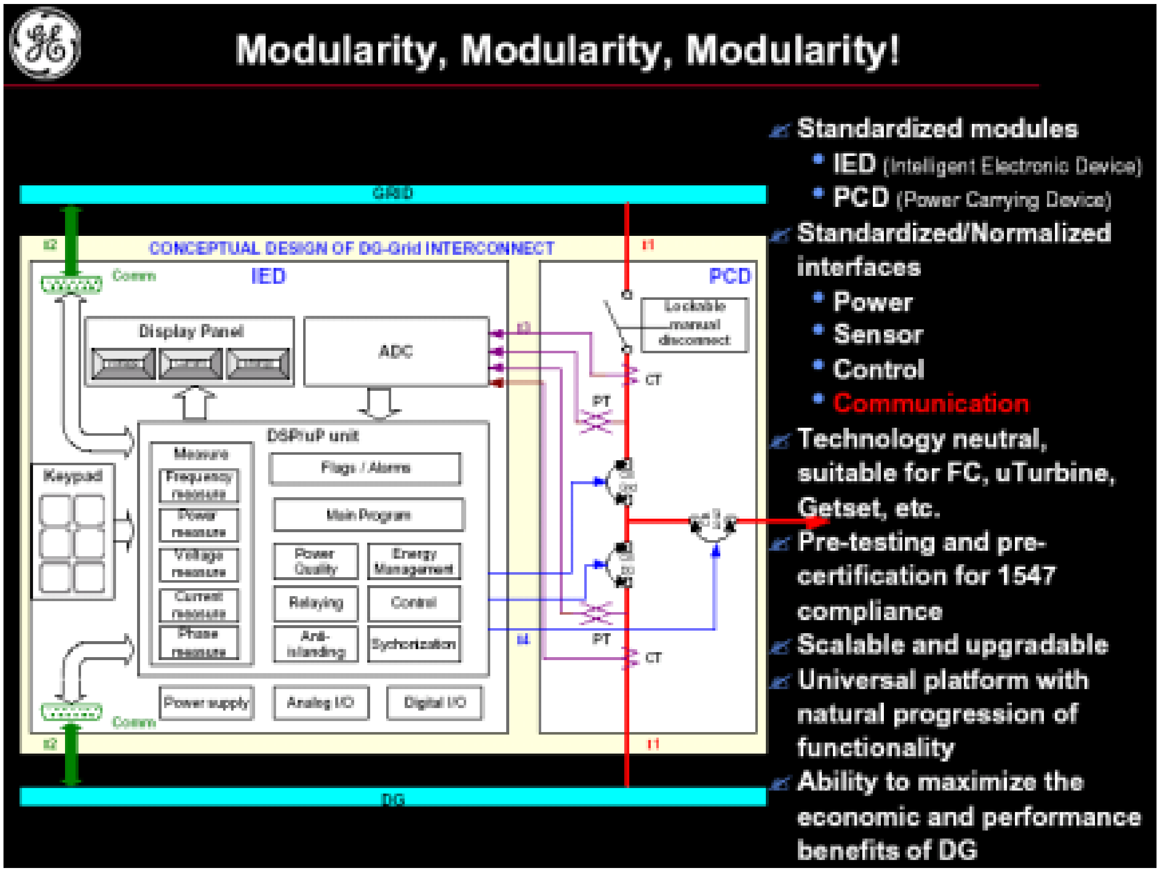


Figure 5-1. GE modular UIT block diagram

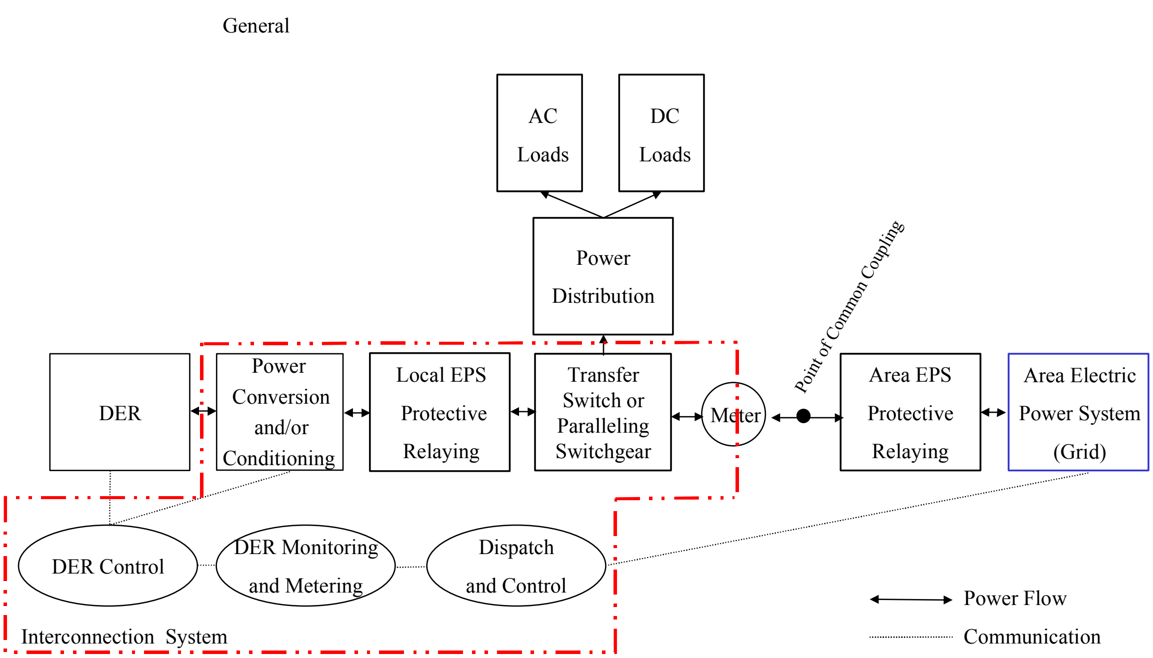


Figure 5-2. Resource Dynamics Corp. modular UIT block diagram

Resource Dynamics Corp.'s version of the modular UIT incorporated a two-track design, illustrated in Figure 5-2 as a power flow and a communication flow.

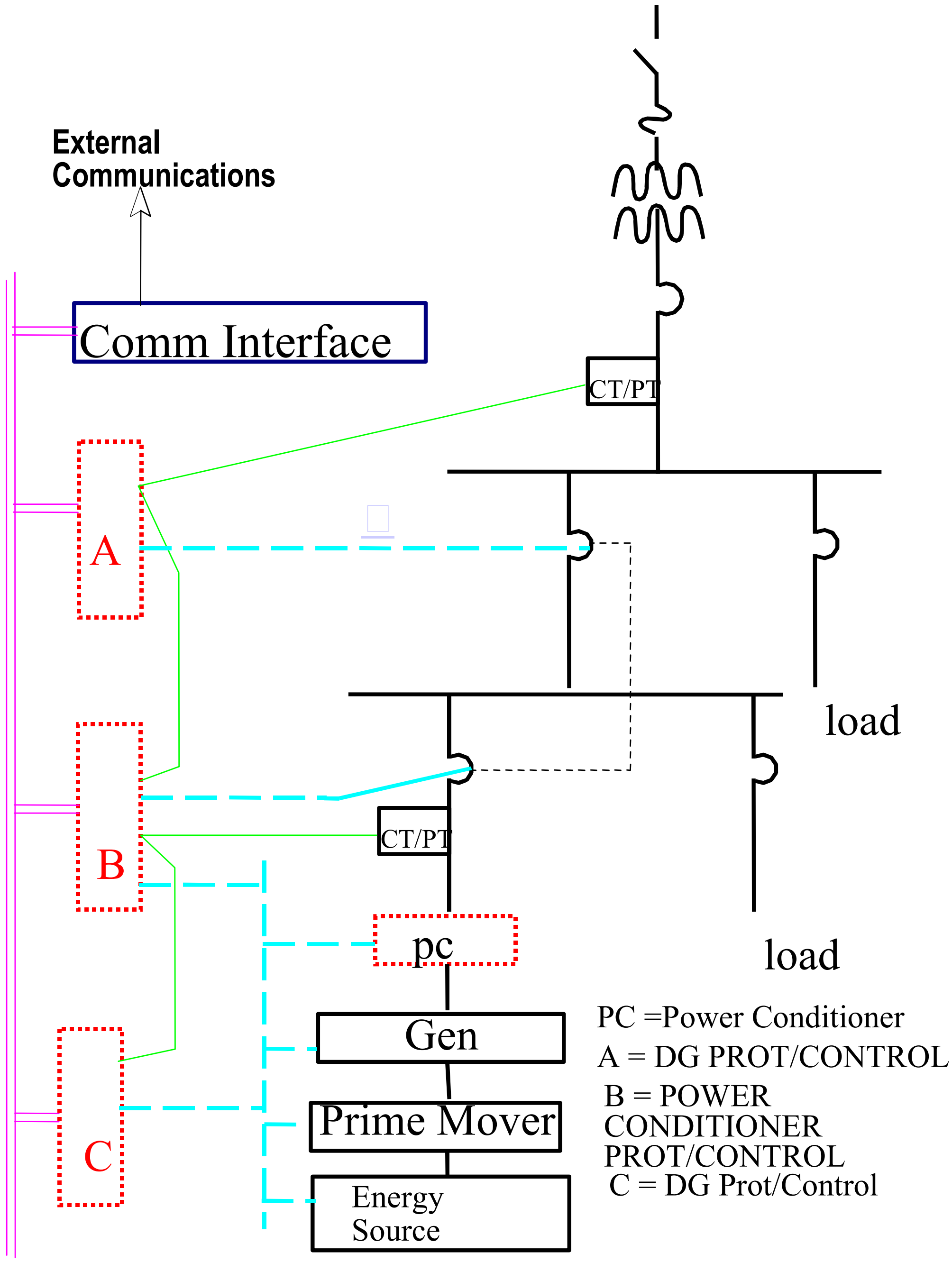


Figure 5-3. Koepfinger modular UIT block diagram

Mr. Koepfinger's block diagram, shown in Figure 5-3, represents the UIT with a common bus structure as another example of interface standardization. The diagram depicts both optional and required items. These include:

- Red/short-dashed optimal items to be included somewhere in the UIT
- A common data box that the DER would plug into and a common protocol
- Control systems that can be either independent or dependent. (Blue/long-dashed lines indicated data lines and control lines.)
- Communication systems
- An optional power conditioner.

Functions can be placed in any of several physical boxes or into one box. In addition, as far as the boxes are concerned, each could be produced by a different manufacturer or all produced by one manufacturer.

Group comments included:

- Diagrams need to distinguish between DER and EPS protection because the concern of the DER owner will be protecting that asset.
- The data communicated and the speed at which it is communicated varies by installation. It can be a large quantity of data at very high speeds or the simplest of control and communications.
- The diagrams represent single-unit installations. With higher penetration, you simply expand or duplicate your UIT. It is important now, though, to just look at the fundamentals and the bottom-most requirements. That way, if you have multiple units, you know at the very least you can just put in multiple UITs.

Participants cautioned again that these figures are representations and ideas. More discussion will be necessary to capture in a standard format the UIT concept.

5.2.4. UIT Functions and DER Size

Regarding the list of UIT functions, would there be any differences by size?

Figure 5-4 depicts requests to interconnect DR in California from November 2000 to May 2002 by size. This was discussed to examine if UIT functions would differ over the size range.

- Participants indicated no differences in functionality based on the size of the DER unit.
- Although basic functionalities remain the same, decreasing costs is critical, as this in turn lowers the size of the DER that can economically be interconnected.
- Net metering for small units and better controls for large gas turbines were both considered additional capabilities, not basic functions.

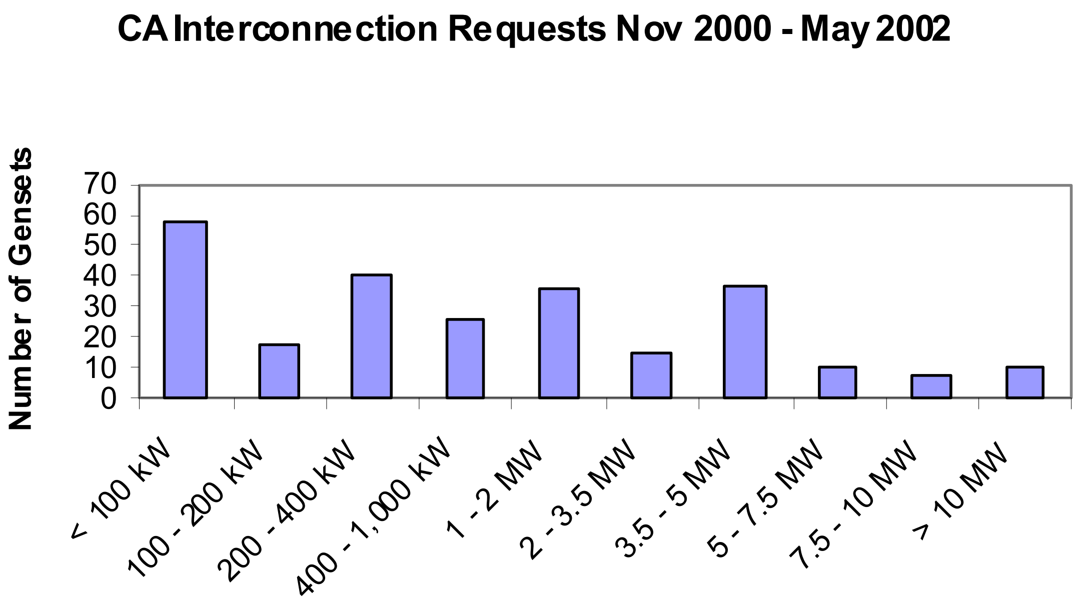


Figure 5-4. DER interconnection size ranges

5.2.5. Feasibility and Potential Roadblocks

Key points and insights from this discussion included:

- Object models will be important for self-configuration and plug-and-play operation.
- Industry participants expressed a strong opinion that the application firmware/software should not be standardized because this is critical to product differentiation and protecting the companies' proprietary property.

6. Session 5: Moving Forward — Next Steps for the UIT Development and Wrap-Up

To build a foundation for moving forward with UIT development, workshop participants were asked:

- What are the next steps to progress the UIT development effort?
- What approach might we use to accomplish these next steps?

Participants supported the concept of a UIT and felt that its adoption would result in lower costs for interconnection and increased use of DER. The group identified a series of "next steps" for moving forward with the development of a UIT. Among the suggested steps were:

- Develop working definitions for each of the UIT functions identified at the workshop so that everyone understands what is being discussed (separating basic functions from optional additional capabilities).
- Develop functional block diagrams of interconnection systems for a variety of DER configurations to aid in synthesizing the UIT.
- Develop a list serve of reviewers. Distribute the function and feature definitions via the list serve and collect and synthesize comments into a clear definition of what a UIT device should include.
- Collect customer input on what their requirements for a UIT would be. This may include DER installers, utilities, and PUCs.
- Convene a one-day workshop with a synchronous design group with a mandate to develop a UIT requirements document. This group would:
  - Determine what common building blocks might exist in a UIT for synchronous machines
  - Develop a draft version of UIT diagrams (with functions, modules, and interfaces) for alternative DER applications.
- Convene a one-day workshop with an inverter design group with a mandate to develop a UIT requirements document. This group would:
  - Adapt and modify the synchronous UIT diagrams as necessary to the inverter situation (with functions, modules, and interfaces) for alternative DER applications
  - Determine what common building blocks might exist in a UIT for synchronous and inverter machines
  - Develop an expanded UIT requirements document.
- Convene a two-day workshop of the combined synchronous and inverter design groups to discuss and resolve differences in the requirements documents and UIT diagrams.
  - Further define the individual pieces within each UIT block diagram
  - Define the interfaces between each common building block piece, especially noting any parameters that may influence standards development
  - Determine how to best work with standards organizations to move toward the adoption of and/or inclusion of the design group's technical requirements document into new UIT standards and protocols as well the updating of other relevant standards documents.

Possible additional steps could include:

- Develop and distribute educational materials to stakeholders.
- Develop interconnection case studies to examine commonalities in interconnection functions and technologies.
- Work with stakeholders to develop type-testing certification processes.

Joseph Galdo and Dick DeBlasio ended the workshop by thanking the participants for their input and participation.

Appendix A. Presentations

"UIT Concept and Benefit Overview," Paul L. Lemar, Jr., Resource Dynamics Corporation

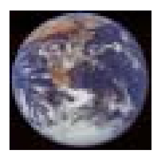
Universal Interconnection Technology Workshop

July 25-26, 2002 Chicago, IL

Workshop Overview

Universal Interconnection Technology Workshop

Workshop Goals



- Examine the need for a modular universal interconnection technology.
- Identify UIT functional and technical requirements.
- Assess the feasibility of and potential roadblocks to the UIT.
- Create an action plan for UIT development.

Universal Interconnection Technology Workshop

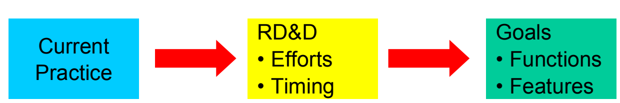
2

What is a UIT?

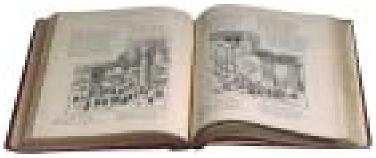
- Stakeholders hold that the “art” of interconnecting DER can be improved, simplified, made more efficient and less costly
- The UIT promises to be a combination of functions of previously unrelated components into a more standardized, integrated, and modular approach

Agenda - Four Sessions

- The vision: UIT functions, needed functionality, and features
- Where we are: current practice
- How we get from where we are to the vision: technology challenges and RD&D solutions
- How to move forward



White Papers



- Universal Interconnect Needs and Trends - GE
- Emerging DER Networks - Encorp
- www and Facility Electric Power Management - ASCO
- Associated Barriers to Distributed Generation - Cutler-Hammer
- Overview of Currently Available UIT-Like Systems - RDC
- Universal Interconnection Technology - Advanced Energy

Universal Interconnection Technology Workshop

5

Presentations

- UIT Functions, Needed Functionality and Features
  - GE
  - Encorp
- Current Practice with Packaged Systems
  - ASCO
  - Cutler-Hammer
  - RDC
- Technology Challenges and R&D Solutions
  - Advanced Energy

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6

Group Exercises

- What are minimum and optional UIT functions?
- How can these functions be organized into blocks (modules)?
- What are the key features a UIT should address?
- How well do current UIT-like functions and features perform?
- What functions will increase utility adoption of DER?
- What DER unit size(s) might require different UIT designs?
- Where should RD&D efforts focus?
- What sequence should RD&D be performed in?
- What should the UIT development effort look like?
- What additional standards, testing and certification are required?
- What is the proper Federal role?
- Where do we go from here?

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7

Level of Detail

- Discuss UIT from the "big picture" level, but also specific design issues
- Address marketplace needs and challenges
- UITs can remove many of the current barriers to DER

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8

Expected Outcomes

- Describe and prioritize efforts
- Define DOE’s role
- Identify “show stoppers” and how to overcome them

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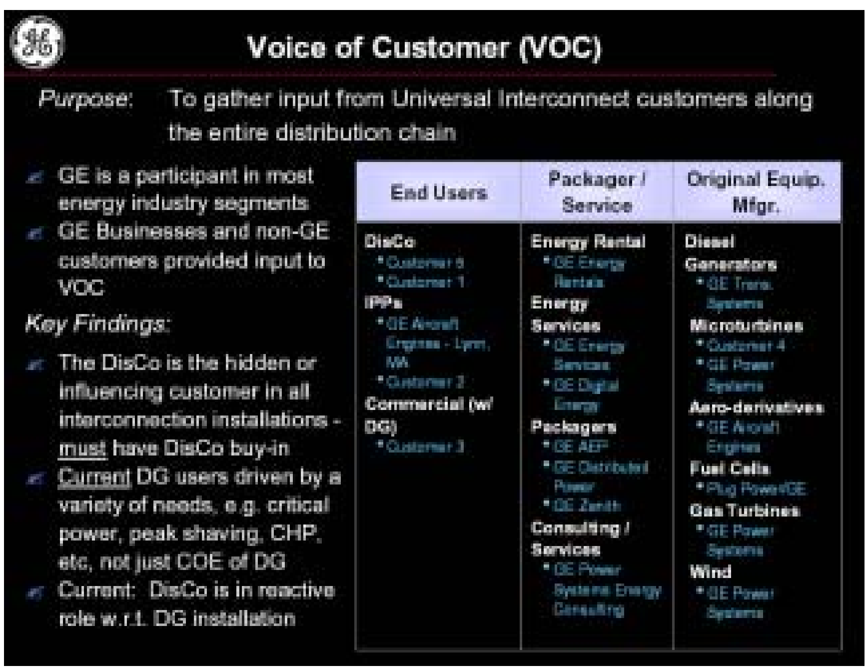
9

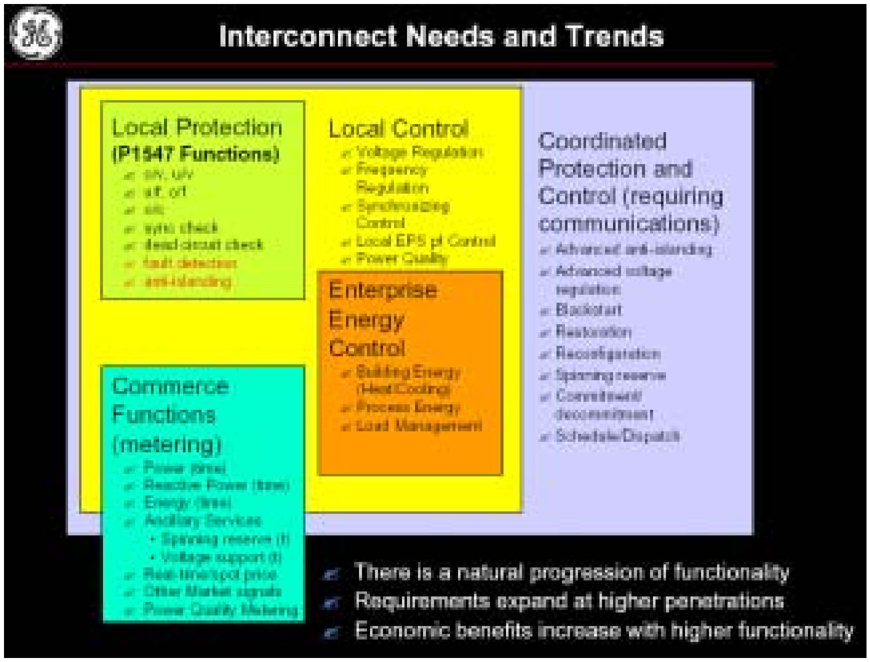
"Universal Interconnect Needs and Trends," Dr. Sam Ye, GE Global Research Center



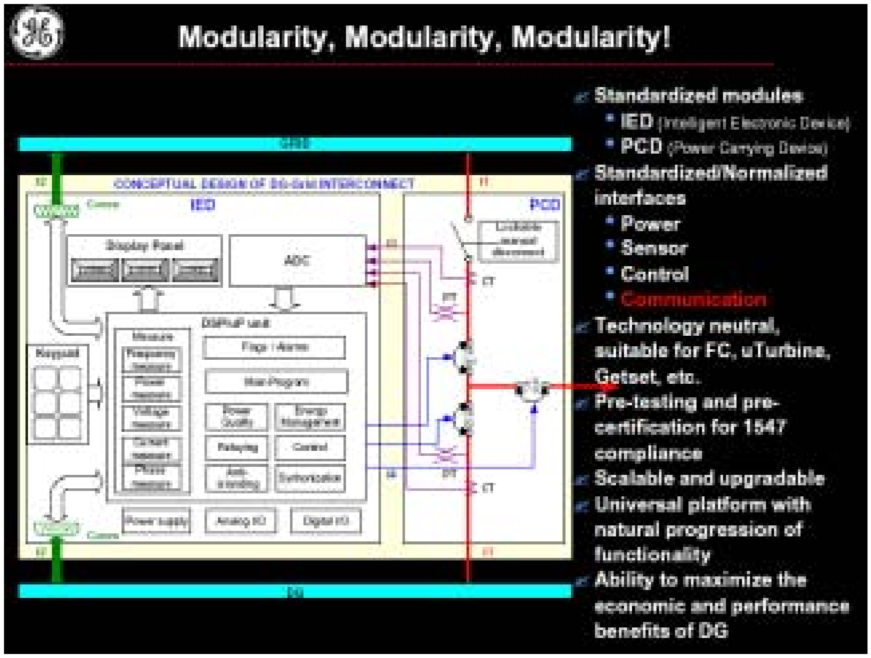
Magnitude of Complexity

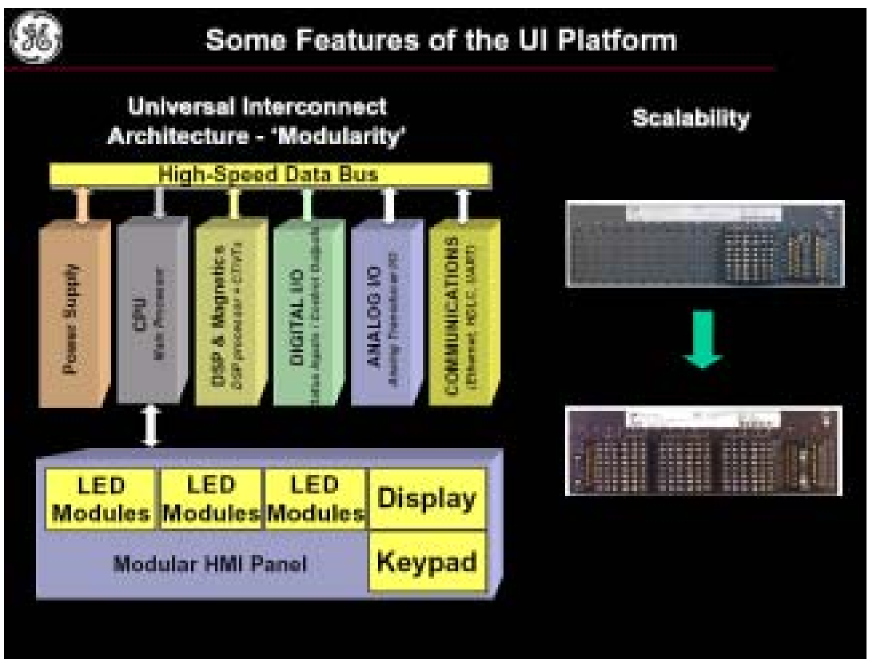
Shape the Vision

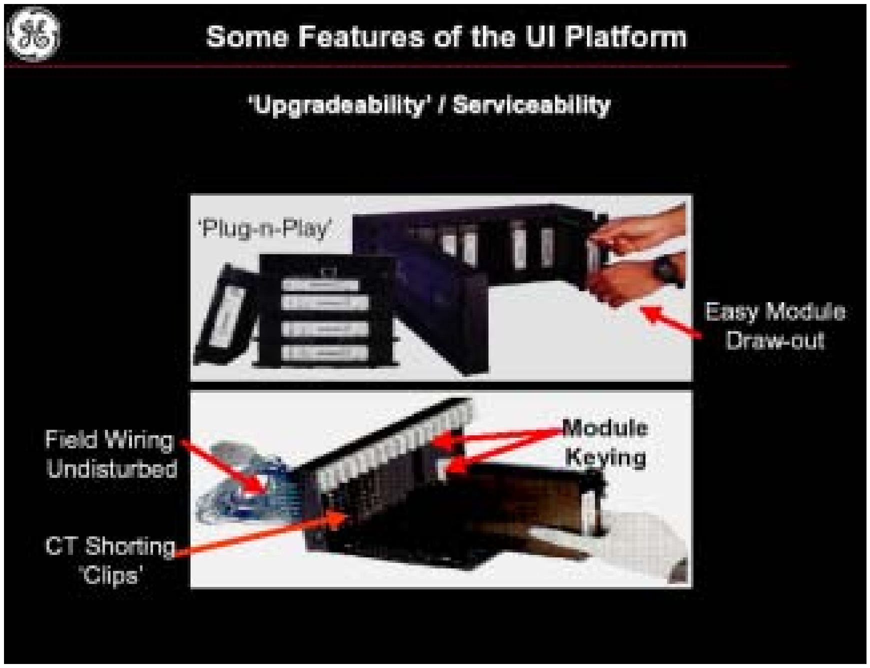
Where are we going?

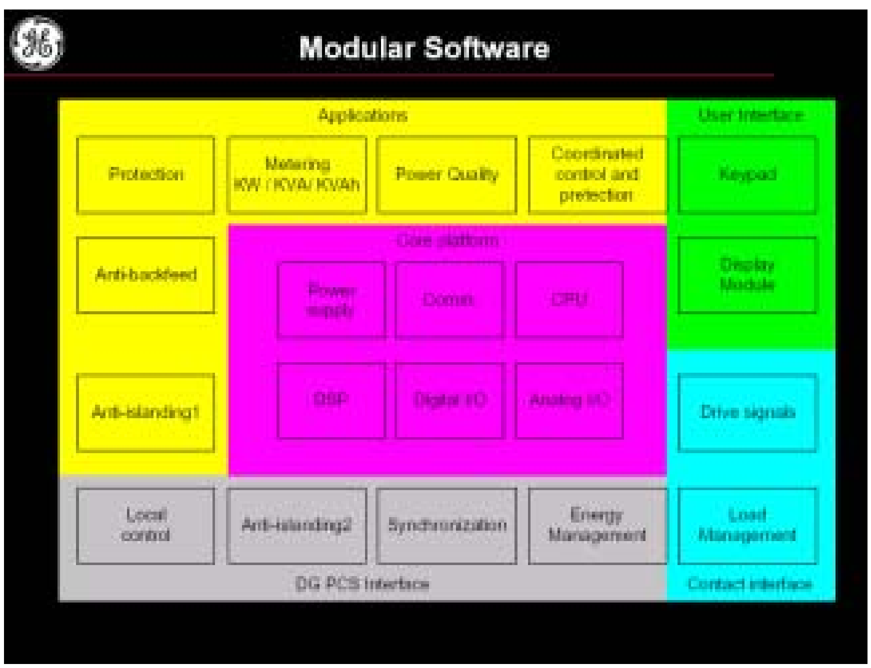

Interconnect Needs and Trends
Local Protection
(P1547 Functions)
sync check
dead circuit check
fault detection
anti-islanding
Local Control
Voltage Regulation
Frequency Regulation
Synchronizing Control
Local EPS pf Control
Power Quality
Coordinated Protection and Control (requiring communications)
Advanced anti-islanding
Advanced voltage regulation
Blackstart
Restoration
Reconfiguration
Spinning reserve
Commitment/ decommitment
Schedule/Dispatch
Enterprise Energy Control
Building Energy (Heat/Cooling)
Process Energy
Load Management
Commerce Functions (metering)
Power (time)
Reactive Power (time)
Energy (time)
Ancillary Services
Spinning reserve (t)
Voltage support (t)
Real-time/spot price
Other Market signals
Power Quality Metering
There is a natural progression of functionality
Requirements expand at higher penetrations
Economic benefits increase with higher functionality

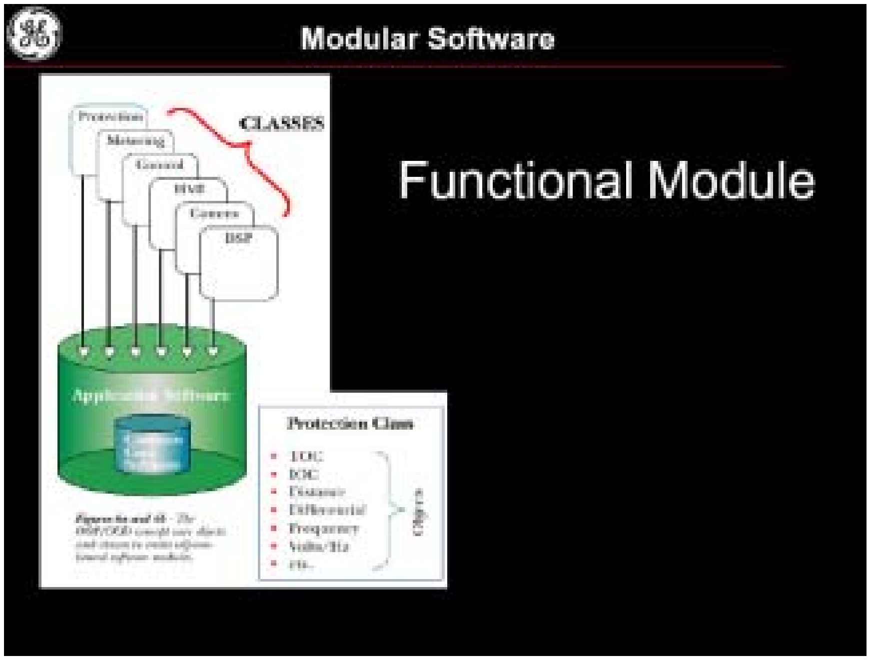

Look for Solutions
How do we get there?

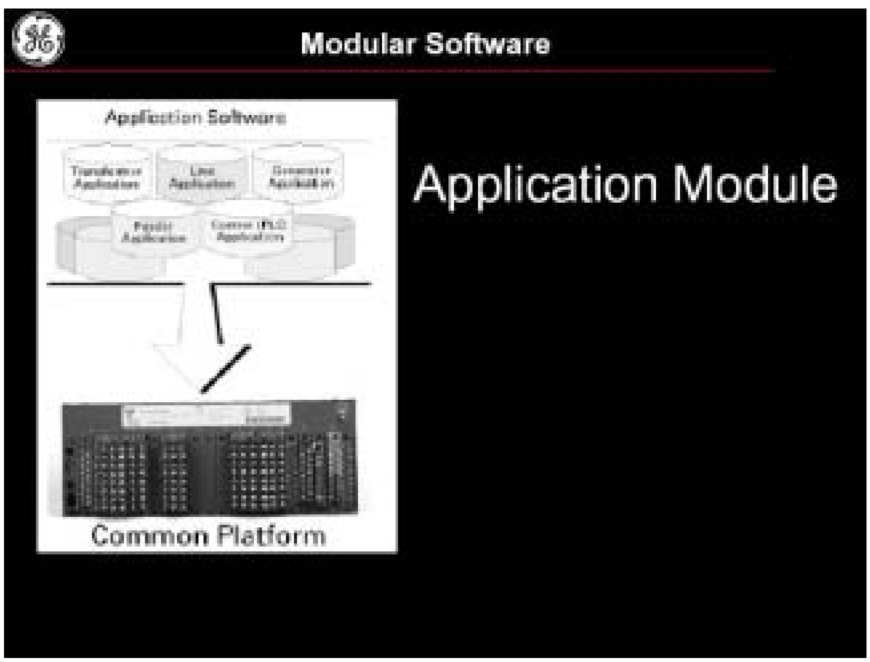

Modularity, Modularity, Modularity!
CONCEPTUAL DESIGN OF DG-Grid INTERCONNECT
IED
PCD
Display Panel
ADC
DSP/uP unit
Keypad
Flags / Alarms
Main Program
Relaying
Control
Power supply
Analog I/O
Digital I/O
DG
Standardized modules
IED (Intelligent Electronic Device)
PCD (Power Carrying Device)
Standardized/Normalized interfaces
Power
Sensor
Control
Communication
Technology neutral, suitable for FC, uTurbine, Genset, etc.
Pre-testing and pre-certification for 1547 compliance
Scalable and upgradable
Universal platform with natural progression of functionality
Ability to maximize the economic and performance benefits of DG

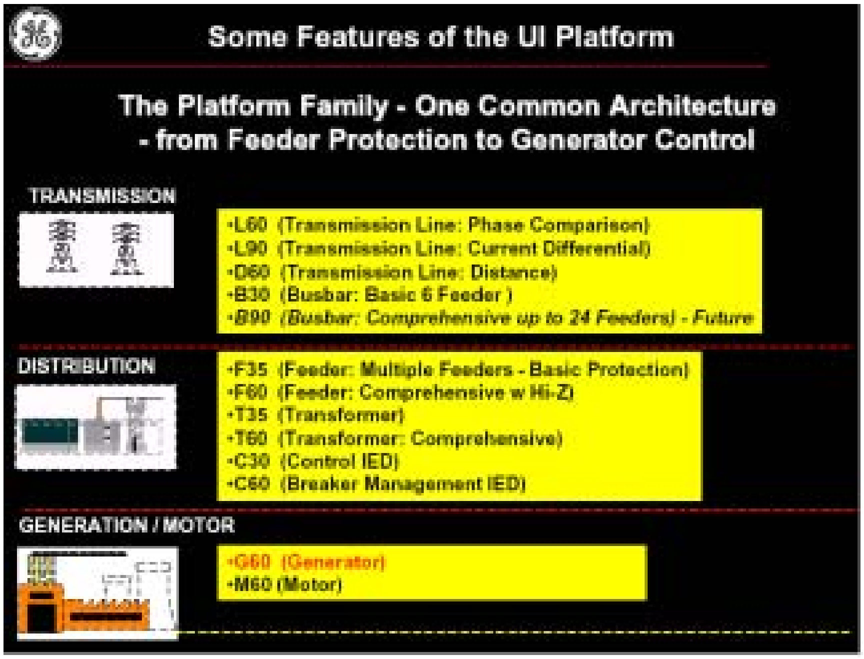

Some Features of the UI Platform
Universal Interconnect Architecture - 'Modularity'
Scalability
High-Speed Data Bus
Power Supply
CPU
DSP & Magnetics
DIGITAL I/O
ANALOG IO
COMMUNICATIONS
LED Modules
LED Modules
LED Modules
Display
Modular HMI Panel
Keypad


Some Features of the UI Platform
'Upgradeability' / Serviceability
'Plug-n-Play'
Easy Module Draw-out
Field Wiring Undisturbed
Module Keying
CT Shorting 'Clips'


Modular Software
Applications
User Interface
Protection
Metering KW / KVA/ KVAh
Power Quality
Coordinated control and protection
Keypad
Anti-backfeed
Core platform
Power supply
CPU
Display Module
Anti-islanding1
DSP
Digital I/O
Analog I/O
Drive signals
Local control
Anti-islanding2
Synchronization
Energy Management
Load Management
DG PCS Interface
Contact interface

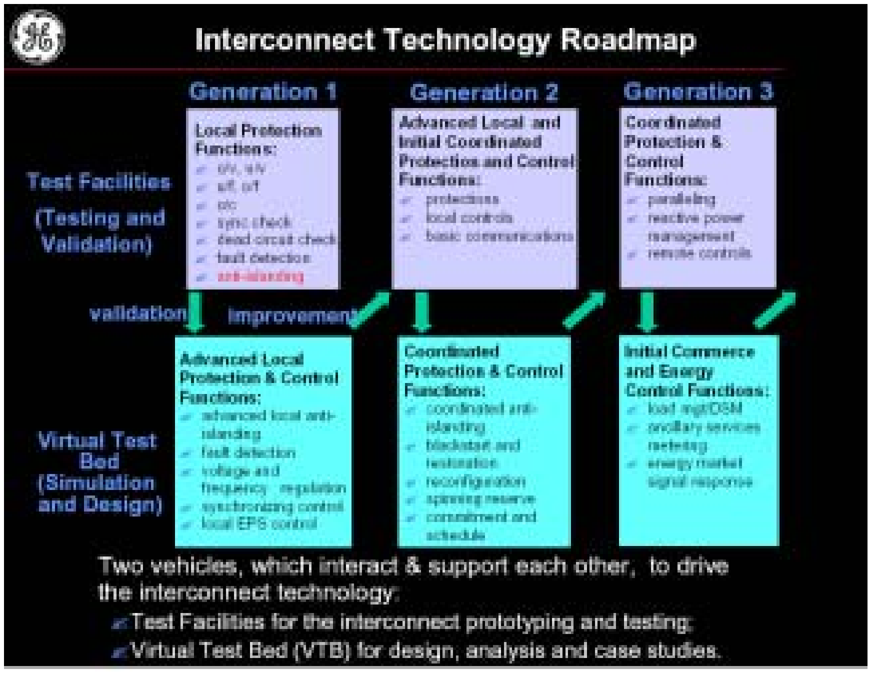

Modular Software
CLASSES
Functional Module
Protection Class
Objects

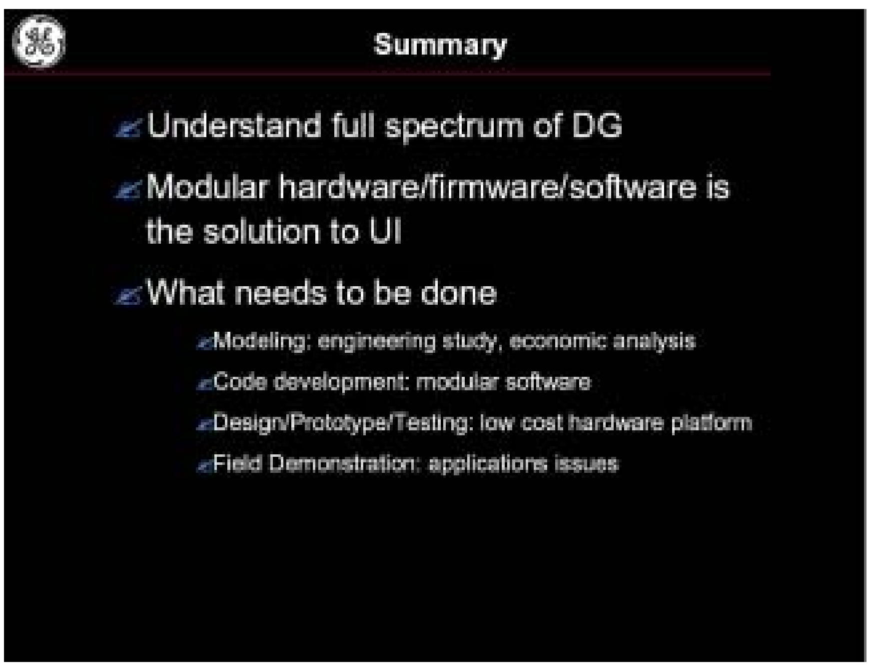

Modular Software
Application Software
Application Module
Common Platform



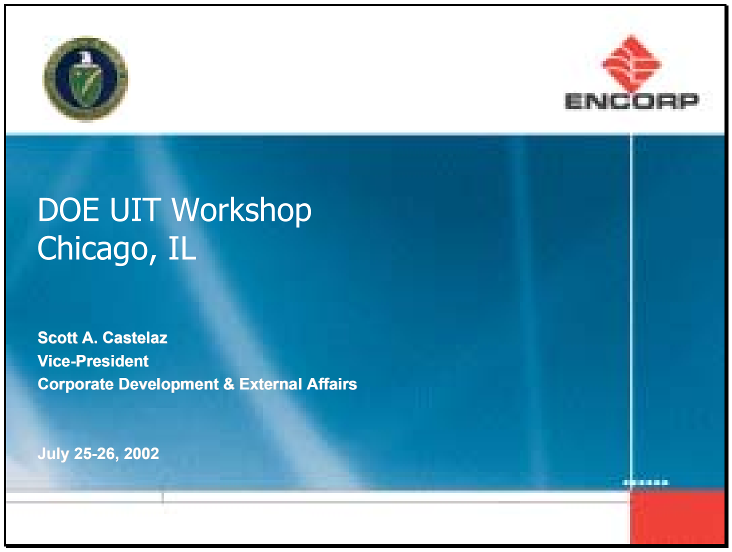
Some Features of the UI Platform
The Platform Family - One Common Architecture
- from Feeder Protection to Generator Control
TRANSMISSION
•L60 (Transmission Line: Phase Comparison)
•L90 (Transmission Line: Current Differential)
•D60 (Transmission Line: Distance)
•B30 (Busbar: Basic 6 Feeder)
•B90 (Busbar: Comprehensive up to 24 Feeders) - Future
DISTRIBUTION
•F35 (Feeder: Multiple Feeders - Basic Protection)
•F60 (Feeder: Comprehensive w Hi-Z)
•T35 (Transformer)
•T60 (Transformer: Comprehensive)
•C30 (Control IED)
•C60 (Breaker Management IED)
GENERATION / MOTOR
•G60 (Generator)
•M60 (Motor)

UI Business Path – GE at Play!
LV
UI
LV
MV
Recip
Fuel Cell
Wind
SOFC
MicroGrid


Interconnect Technology Roadmap
Generation 1
Generation 2
Generation 3
Test Facilities
(Testing and Validation)
Local Protection Functions:
o/v, u/v
u/f, o/f
o/c
sync check
dead circuit check
fault detection
anti-islanding
Advanced Local and Initial Coordinated Protection and Control Functions:
protections
local controls
basic communications
Coordinated Protection & Control Functions:
paralleling
reactive power management
remote controls
validation
improvement
Virtual Test Bed (Simulation and Design)
Advanced Local Protection & Control Functions:
advanced local anti-islanding
fault detection
voltage and frequency regulation
synchronizing control
local EPS control
Coordinated Protection & Control Functions:
coordinated anti-islanding
blackstart and restoration
reconfiguration
spinning reserve
commitment and schedule
Initial Commerce and Energy Control Functions:
load mgt/DSM
ancillary services
metering
energy market signal response
Two vehicles, which interact & support each other, to drive the interconnect technology:
Test Facilities for the interconnect prototyping and testing;
Virtual Test Bed (VTB) for design, analysis and case studies.


Summary
Understand full spectrum of DG
Modular hardware/firmware/software is the solution to UI
What needs to be done
Modeling: engineering study, economic analysis
Code development: modular software
Design/Prototype/Testing: low cost hardware platform
Field Demonstration: applications issues

“Emerging DER Networks,” Scott Castelez, Encorp



Introduction to Encorp

ENCORP

ENCORP VISION STATEMENT

To be recognized as the world's leading provider of network technology and infrastructure-management solutions for the distributed energy market.

ENCORP MISSION STATEMENT

To develop and implement real-time, distributed energy-focused solutions for a wide range of applications through innovative products and services, which are technology-neutral, easily networked, supported 24/7 and deliver high-level, enterprise-wide functionality for our clients' growing needs.

WHAT DO WE DO?

We develop and market software and hardware technology solutions for the communication, control, and networking of distributed energy.

pick your power.

3

Introduction to Encorp

ENCORP

- ✓ Leading Provider of "*Technology-Neutral*" Grid Interconnection, Network Integration, & Control Solutions for the Distributed Resources Market
- ✓ Uniquely positioned in the growing Power Quality, Reliability, & Load Management Segments
- ✓ Sustainable Competitive Advantages
  - ✓ Proprietary, technology-based "first-mover"
  - ✓ Broad project solutions experience
  - ✓ Excellent reputation within the DR sector
  - ✓ Demonstrated compatibility across wide range of third-party equipment & systems

pick your power.

4

Encorp by the Numbers

ENCORP

- ✓ Total MW Controlled by Encorp Products: 560+
- ✓ Total Number of Enpower Controls Shipped (6/30/02): 1,338
  - ✓ - 2001 438
  - ✓ - 1997-2000 ~900
- ✓ Total Number of Encorp Customers: 172
- ✓ Total Number of Commercial Products: 13
- ✓ Total Number of New Products Planned: 8

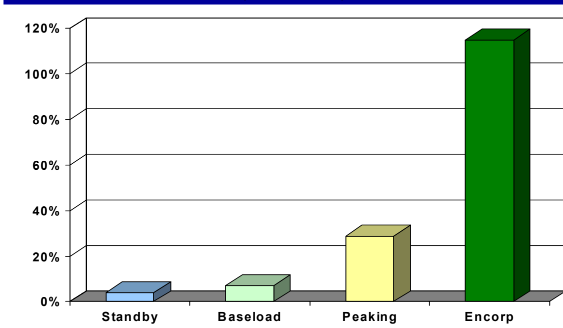
pick your power.

5

Encorp's growth has greatly exceeded all comparable DG markets.

ENCORP

Compound Annual Growth Rate: Market Segments vs. Encorp Revenue
(1997 to 2001)



Sources: Encorp, Arthur D. Little & Power Systems Research

pick your power.

6

What Sets Encorp Apart From The Rest?

- ✓ Control, IT & Telecom Communications, Local and Remote Software Products
- ✓ Developed products that communicate with inverter-based technologies
- ✓ Utility Interconnect, Utility Business Needs, Distributed Generation, Electric and Gas Tariff Understanding
- ✓ Employee experience in reciprocating engines, turbines, controls, software, and power generation
- ✓ Leadership in key regulatory policy & DER industry affairs
- ✓ Entrepreneur spirit within the employees
  - ✓ "Take It On"
  - ✓ "Get It Done"

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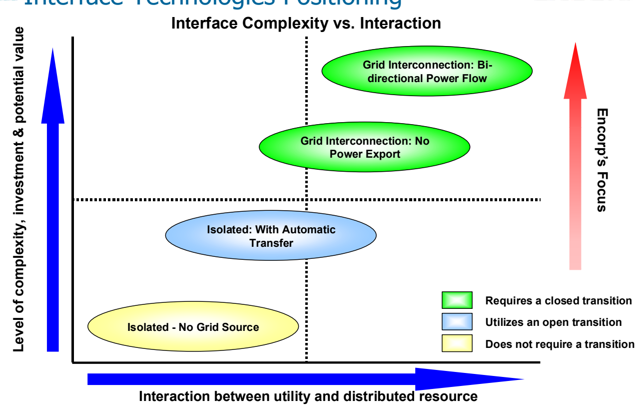
Interface Technologies Positioning



Source: Arthur D. Little & Encorp

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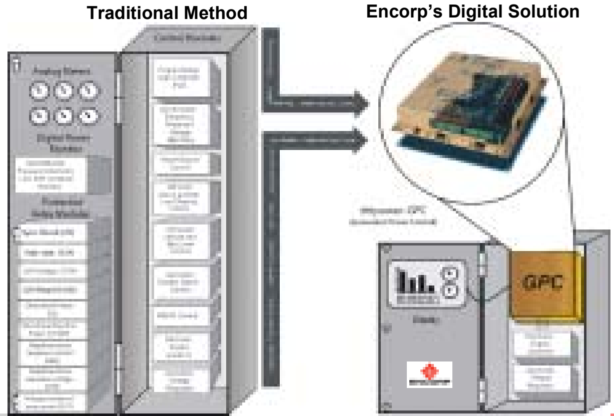
Encorp's Differentiator – The Gold Box & Remote Energy Automation

ENCORP

Traditional Method **Encorp's Digital Solution**



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9

Product Offerings

ENCORP POWER generator power control

- ✓ **The Generator Power Controller, or GPC, is the world's first truly integrated control system, combining the functionality of several traditional control modules, communications and protective relays into a single, solid-state assembly, or "gold box".**
- ✓ **The GPC offers the provides the following functionality**
  - **Engine start/stop sequencing**
  - **Engine monitoring**
  - **Generator control functions**
  - **Utility and generator protective relay functions**
  - **Power metering (energy)**
  - **Power quality monitoring (harmonics)**
  - **PLC Logic and network communications for I/O expandability**
  - **Local & remote PC communications interface**

pick your power.

10

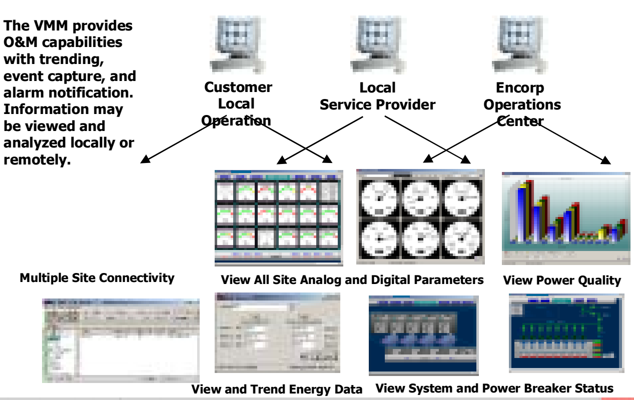
Product Offerings

ENCORP INTELLIGENCE energy automation software

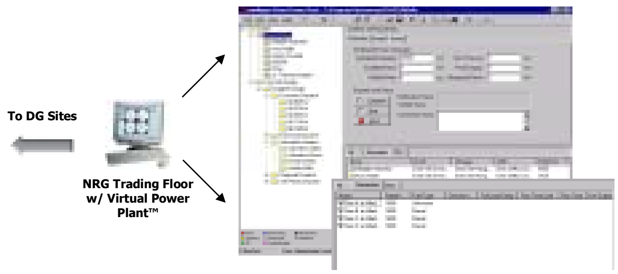
- ✓ Windows®-based applications create a simple, user-friendly interface for applications that require local and/or remote monitoring and control capabilities
- ✓ Real-Time Economic optimization of a single resource, multiple resources within a site, and aggregated assets across large geographies - hedging strategies for traders/marketers
- ✓ 'Plug 'n Play' operations & maintenance capability - master gateway
- ✓ Interface to the Power Exchange (PX), an Independent System Operator (ISO), or a Regional Transmission Organization (RTO)

Virtual Maintenance Monitor™ Software

The VMM provides O&M capabilities with trending, event capture, and alarm notification. Information may be viewed and analyzed locally or remotely.



Virtual Power Plant™ Software



The Virtual Power Plant™ allows for aggregation and multiple grouping of distributed generation sites. The software will allow a user to dispatch single engines, single sites, or multiple sites that are grouped. You can view multiple levels of the site information and drill down to detailed site information on the generators, fuel type, rated kW, emissions, total capacity, location, etc.

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13

Product Offerings

ENCORPPOWER automatic paralleling switch

- **The Automatic Paralleling Switch is a fully integrated control and display assembly offering grid interconnection capability for gensets up to 350 kW**
- **Relatively small size and cost makes peak shaving possible for small commercial and retail enterprises**
- **Several discrete components (electromechanical and solid state relays) replaced by the Generator Power Controller, or GPC**
- **Additional functionality provided when combined with our suite of software applications – communications, monitoring, control and aggregation of gensets**

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14

Product Offerings

- Low voltage and medium voltage offering of switchgear for use in grid interconnection, generator paralleling and automatic transfer switch configurations
- Several discrete components (electromechanical and solid state relays) replaced by the Generator Power Controller, or GPC
- Additional functionality provided when combined with our suite of software applications – communications, monitoring, control and aggregation of gensets
- Mass Customization possible due to the ability to configure the GPC by modifying firmware

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15

Encorp Services

- **Application Engineering Services**
  - Switchgear systems design
  - Software design & network configuration
  - Local & remote communications
  - Single & three-phase power designs
- **Professional Engineering Services**
  - Generator to utility interconnect engineering
  - Ground fault/short circuit studies
  - Breaker coordination studies
  - Utility Rate & ROI analysis studies
- **Service Engineering**
  - Startup & commissioning
  - Maintenance & operation
  - Training (in-house & onsite)
- **Technical Support Services**

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16

Project Development – DG & Cogen

ENCORP ASSISTANCE technical services

- **Design onsite power generation plants paralleled with the utility network**
- **Cogeneration equipment options**
  - **Lowered operating expenses through cheaper energy**
  - **Increased power reliability through onsite power generation**
- **Provide turnkey engineering, procurement & construction services**
- **Secure financial & 3rd party plant ownership**
- **Provide O&M services**
- **Secure 3rd ESP supply options**
- **Utilize incentive programs to increase savings**

pick your power. 17

Encorp Managed Service (Report Level Offerings)

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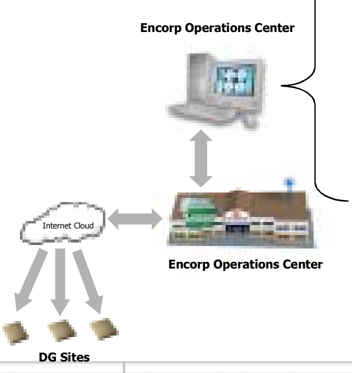

Report Levels (Daily, Weekly, Monthly, Yearly)

1. Service Provider
- Operator Log Report
- History Equipment Maintenance Log
- Heat Rate Analysis Report
- Equipment Malfunction and Alarm Capture Report

2. Energy User
- Gas Usage (BTU) and $Price Invoice
- Electricity Usages (kWh/MWh) Invoice
- Capacity Charge (Fixed Cost of Equipment) Invoice
- Energy Comparison Report

3. Governmental & Utility Agencies
- Emissions Report - Air Board
- Gross & Net MWh Production Report
- Capacity Availability (MW/kW) Report

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Encorp Managed Service (Communications Overview)

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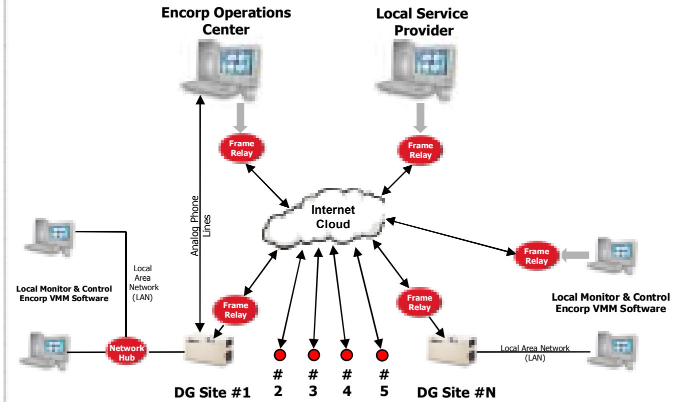


Agenda

ENCORP

1. Introduction to Encorp
2. **Emerging Issues**
3. Capturing the Value
4. Next Steps & Recommendations

Future Networks

ENCORP

Situation: In the next few years, large & robust networks that aggregate DER assets will emerge.

These networks will aggregate a variety of energy technologies:

- ✓ **Reciprocating engines**
- ✓ **UPS**
- ✓ **Fuel cells**
- ✓ **Micro turbines**
- ✓ **PV**
- ✓ **Wind**
- ✓ **Flywheels**

Issues:

- ✓ **Who are the early buyers?**
- ✓ **Which generation technologies will they use?**
- ✓ **What values will the buyers want to capture?**
- ✓ **What technologies will be used to interconnect, control & aggregate DER assets to meet demands of buyers?**

UIT Technologies Have Three Overarching Issues

ENCORP

Technological Issues to Address When Creating UIT Standards

Interconnection

Can a substantial amount of DER be interconnected to both energy delivery systems and to each other for seamless interoperation?

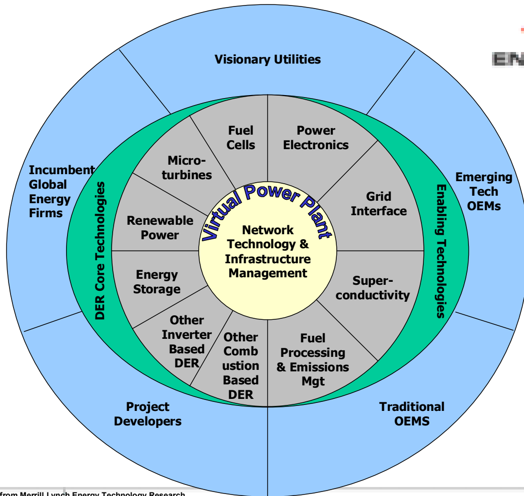
Grid Effects

Would a high penetration of DER have adverse impacts and/or positive effects on an energy delivery systems?

Market Integration

Can DER access robust markets or be exposed to price signals that will maximize benefits to customers and the power system?

Source: Navigant Consulting & Encorp



© Encorp 2002
Adapted in part from Merrill Lynch Energy Technology Research

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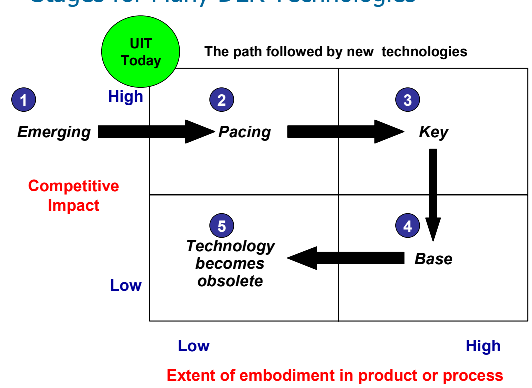
23

UIT Technologies Are at the Earliest Stages for Many DER Technologies



Source: Navigant Consulting & Encorp

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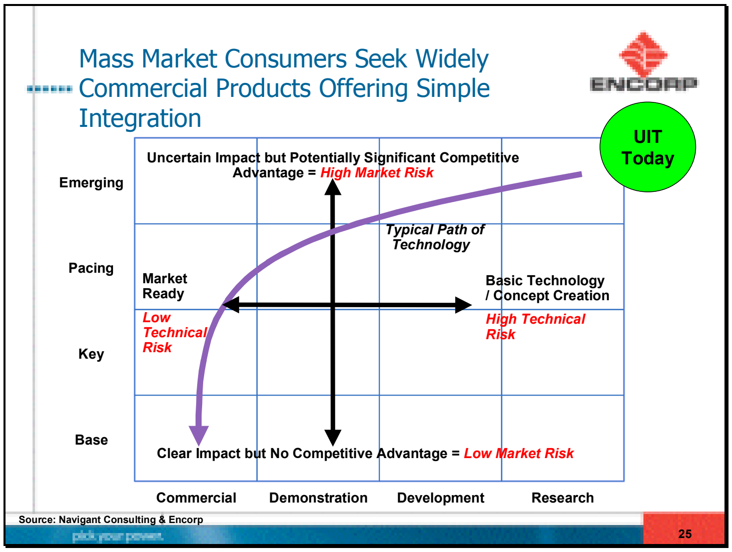
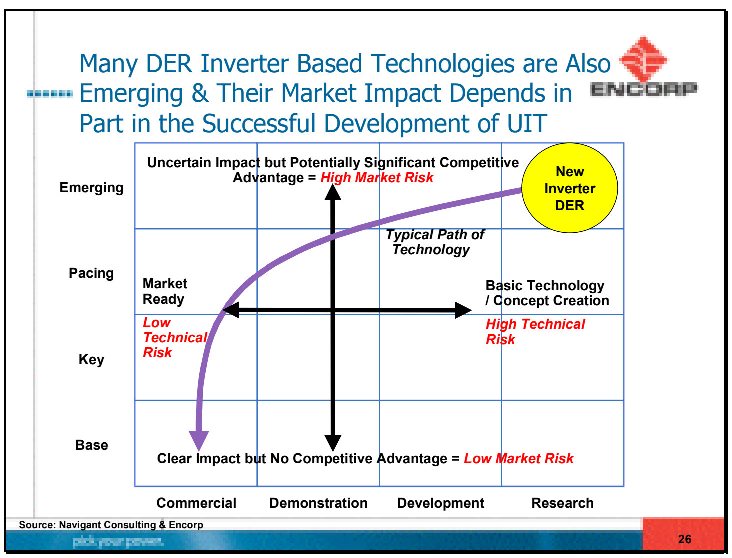
24


Mass Market Consumers Seek Widely Commercial Products Offering Simple Integration
ENCORP
UIT Today
Uncertain Impact but Potentially Significant Competitive Advantage = High Market Risk
Emerging
Pacing
Key
Base
Typical Path of Technology
Market Ready
Low Technical Risk
Basic Technology / Concept Creation
High Technical Risk
Clear Impact but No Competitive Advantage = Low Market Risk
Commercial
Demonstration
Development
Research
Source: Navigant Consulting & Encorp
25


Many DER Inverter Based Technologies are Also Emerging & Their Market Impact Depends in Part in the Successful Development of UIT
ENCORP
New Inverter DER
Uncertain Impact but Potentially Significant Competitive Advantage = High Market Risk
Emerging
Pacing
Key
Base
Typical Path of Technology
Market Ready
Low Technical Risk
Basic Technology / Concept Creation
High Technical Risk
Clear Impact but No Competitive Advantage = Low Market Risk
Commercial
Demonstration
Development
Research
Source: Navigant Consulting & Encorp
26

Current Situation – Inertia is Giving Way to New Technology & Market Realities

There are a number of barriers being addressed by multiple stakeholders today.

Key Issues
✓ Safety – what protective devices are necessary?
✓ Cost effective standards – who pays? How are costs shared between technology developers, utilities & research institutions?
✓ Reliability?
✓ Can interconnection interfaces be made to be user-friendly?
✓ Interconnection between multiple DER units sharing a common bus?
✓ Can communication & control protocols be standardized to create a standard platform for integration with legacy IT systems?

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27

Future Issues to Be Addressed

As the key issues are addressed, new challenges will emerge.

Emerging Issues
✓ Can microgrids be utilized effectively?
✓ Can engineering studies be eliminated, standardized or streamlined?
✓ Is there a limit to the level of DER that a utility system can absorb?
✓ What are the limitations of bi-directional power flows?
✓ What are the informational needs of energy delivery firms with DER deployed in their system?
✓ Can interconnection devices be modular & scalable?

pick your power.

28

Regulatory Barriers

Encorp's Perspective

Key Questions	Answers
✓ Are there safe, reliable, modular & cost-effective interconnection solutions for radial & networked distribution systems? ✓ Can interconnection be made more user-friendly to the end-use consumer? ✓ Can synchronous and inverter based DER units share a common bus? ✓ Can DER assets interoperate with legacy IT systems?	✓ Yes to all questions. ✓ Encorp and other energy technology developers have begun to commercialize solutions that safely & cost-effectively interconnect DER assets with the utility grid and with each other.

Agenda

1	Introduction to Encorp
2	Emerging Issues
3	Capturing the Value
4	Next Steps & Recommendations

As Distributed Energy Resources Multiply in Numbers Increasingly Robust Interface & Communication Architecture is Required

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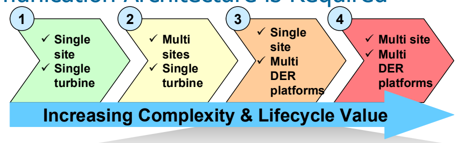

	Stage 1	Stage 2	Stage 3	Stage 4
Grid Interconnection	Often required, but not necessary	Required	Required	Required
Multiple & Hybrid Technology Interoperation	N/A	N/A	Often required, necessary to optimize DER value	Required
Integration with IT & Comm. Networks	Not required	SCADA required, external market integration adds value	SCADA required, external market integration & optimization of DER platforms add value	SCADA required, external market integration & optimization of DER platforms add value

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DER Microgrid

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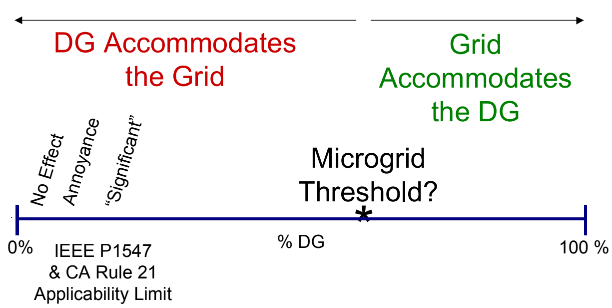

Source: Distributed Utility Associates

pick your power. 32

Technical Considerations

ENCORP

Communications & Controls (none)	←――――→	"Omniscient"
Autonomous	←――――→	"Aggregation Entity" (Highly Coordinated)
Modest data needs	←――――→	Significant data needs
Electricity Delivery	←――――→	Fuel Delivery
Security	←――――→	More Resilient?

0% ――――――――――*―――――――― 100%

Source: Distributed Utility Associates

pick your power.

33

Business Considerations

ENCORP

Individual Actions & Self-interests	←――――→	"Common Good"
Utility Roles	←――――→	None Backup Munis / Co-ops

0% ――――――――――*―――――――― 100%

Source: Distributed Utility Associates

pick your power.

34

Economic Considerations

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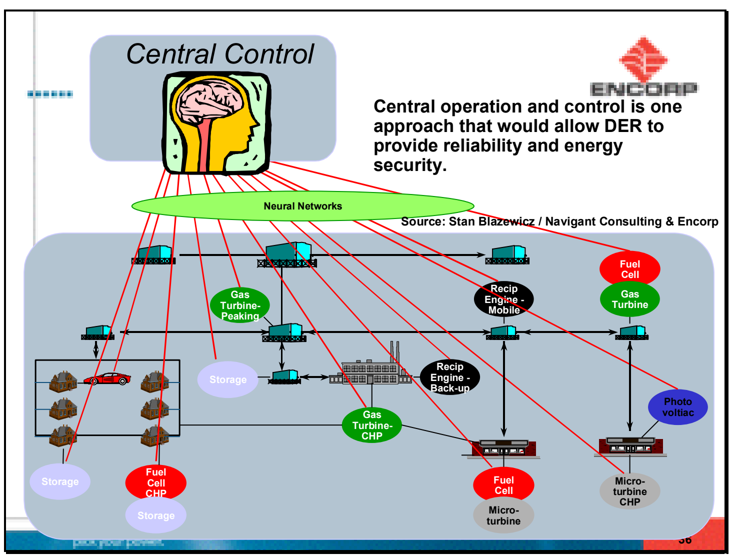
Cost	⟷	**Cost?**
Reliability	⟷	**Reliability?**

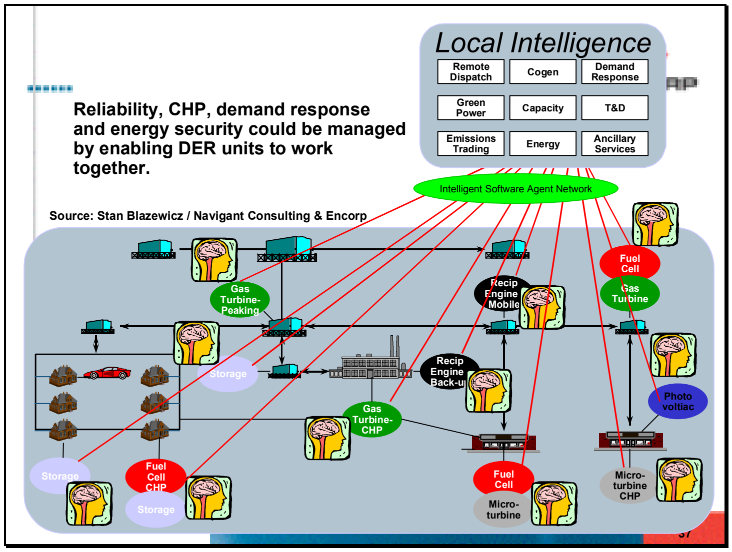
0% —————— * —————— 100%

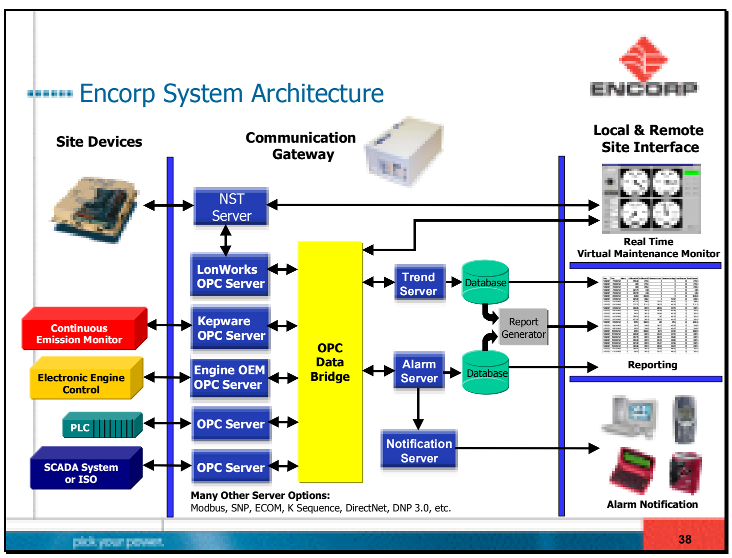
Source: Distributed Utility Associates

pick your power.

35




Local Intelligence
Remote Dispatch
Cogen
Demand Response
Green Power
Capacity
T&D
Emissions Trading
Energy
Ancillary Services
Reliability, CHP, demand response and energy security could be managed by enabling DER units to work together.
Source: Stan Blazewicz / Navigant Consulting & Encorp
Intelligent Software Agent Network
Gas Turbine-Peaking
Storage
Fuel Cell CHP
Gas Turbine-CHP
Recip Engine Mobile
Recip Engine Back-up
Fuel Cell
Gas Turbine
Photo voltaic
Micro-turbine CHP
Micro-turbine
37


Encorp System Architecture
ENCORP
Site Devices
Communication Gateway
Local & Remote Site Interface
NST Server
LonWorks OPC Server
Kepware OPC Server
Engine OEM OPC Server
OPC Server
OPC Server
OPC Data Bridge
Trend Server
Alarm Server
Notification Server
Database
Database
Report Generator
Real Time Virtual Maintenance Monitor
Reporting
Alarm Notification
Continuous Emission Monitor
Electronic Engine Control
PLC
SCADA System or ISO
Many Other Server Options:
Modbus, SNP, ECOM, K Sequence, DirectNet, DNP 3.0, etc.
pick your power.
38

Agenda

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What Comes Next?

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Increased distributed network flexibility, scalability & robustness

- ✓ Market demands multiple applications with multiple DER technologies addressed by a single interconnection system (i.e. demand response meets CHP meets real time pricing meets reciprocating engines meets inverters)
- ✓ The grid is not going away and energy delivery firms will remain central DER stakeholders
- ✓ Federal regulators & legislators may step up to the plate once DER is viewed as valuable to:
  - ✓ Energy independence
  - ✓ Grid security
  - ✓ Environmentally sustainable
  - ✓ Energy efficiency
- ✓ IEEE 1574 may provide technical leadership standards for interconnection. But alone, this is not enough – enduring standards take a long time to evolve
- ✓ State PUCs will remain in the background

Leadership is Required to Get to the Next Technology & Market Levels

ENCORP

- ✓ "Plug and Play" DER interconnection is still far away
- ✓ DER's benefits to the power system, in addition to negative impacts, need to be studied and understood
- ✓ There is no clear understanding of microgrids or of their benefits, operational parameters and control requirements
- ✓ Policy developments must proceed hand-in-hand with technology
- ✓ Integration, optimization, and operation of DER will be vital

Source: Navigant Consulting & Encorp

pick your power.

41

Encorp Supports Collaborative Efforts Across the DER Industry that Address UIT

ENCORP

- ✓ UIT is in early stage research – significant work needs to be done to propel UIT beyond the emerging research phase if the public is to benefit
- ✓ Multiple stakeholders representing the spectrum of DER technologies should be represented to create a truly "universal" standard
- ✓ All applications must be considered for a truly "universal" standard
  - ✓ Parallel
  - ✓ Island
  - ✓ Hybrid (stand alone to parallel)

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42

Last a Reminder: Does UIT Really Matter if DG Cannot Avoid the DSL Debacle?

ENCORP

"A host of new companies were founded to provide digital subscriber line (DSL) connections, but after a short while they went under in droves as the Regional Bell Operating Companies (RBOCs) reasserted their strangleholds on local markets."

-- William Sweet & Elizabeth Bretz
IEEE Spectrum, Jan. 2002

Today's DSL market has little competition. Reliability remains a central issue for mass market consumers.

Source: Gary Nakarado / NREL & Encorp

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43

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Thank You

"www. and Facility Electric Power Management," James M. Daley, PE, ASCO Power Technologies

www. and Facility Electric Power Management

Presented By
James M. Daley, PE
ASCO Power Technologies

EMERSON
Network Power

Focus

- DR < 10 MVA
- Turbine or Reciprocating Prime Mover
- Rating < Host Facility Demand

ASCO Power Technologies

EMERSON
Network Power

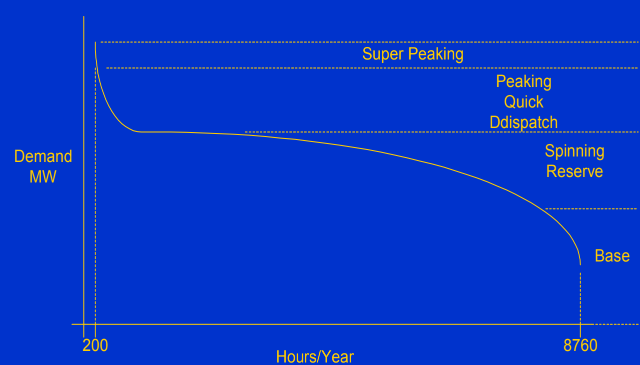
Issues

- Electric power source and use profiles
- Electric Power Grid
- Prime Mover/Generator Control
- Control at the Point of Interconnect
- Relay Scheme

ASCO Power Technologies

Network Power

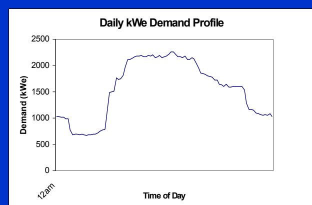
Utility System Needle Peak

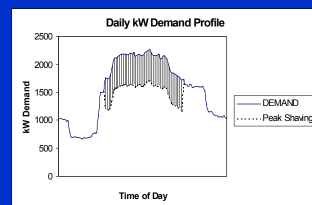


ASCO Power Technologies

Network Power

Facility Demand Profile





ASCO Power Technologies

Network Power

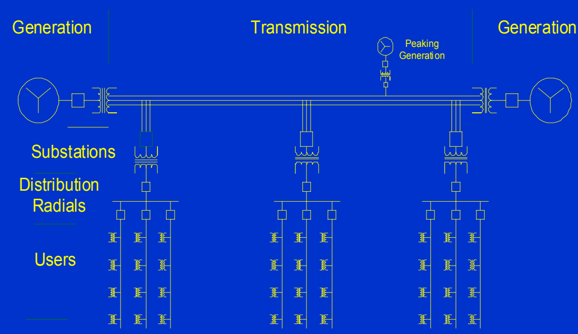
Electric Power Grid

- Distribution Radial
- Networks
  - Spot
  - Grid

ASCO Power Technologies

Network Power

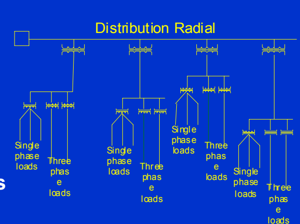
Electric Power Grid



ASCO Power Technologies

Network Power

Distribution Radial

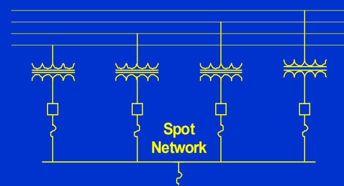


- Transformers
  - Dedicated
  - Shared
- DR < Facility Demand

ASCO Power Technologies

Network Power

Spot Network



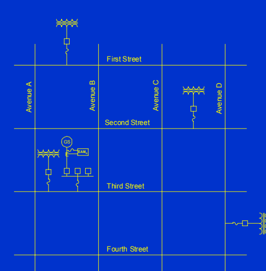
- DR< Facility Demand
- No impact on Network Protectors

ASCO Power Technologies

Network Power

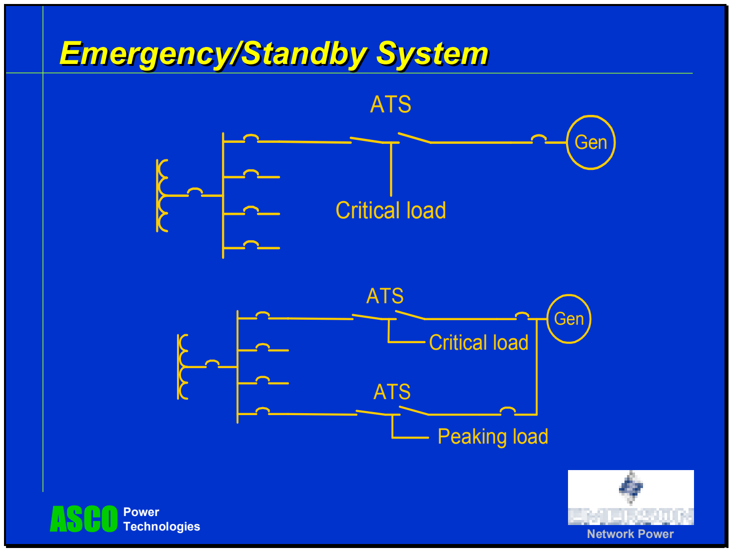
Network Grid

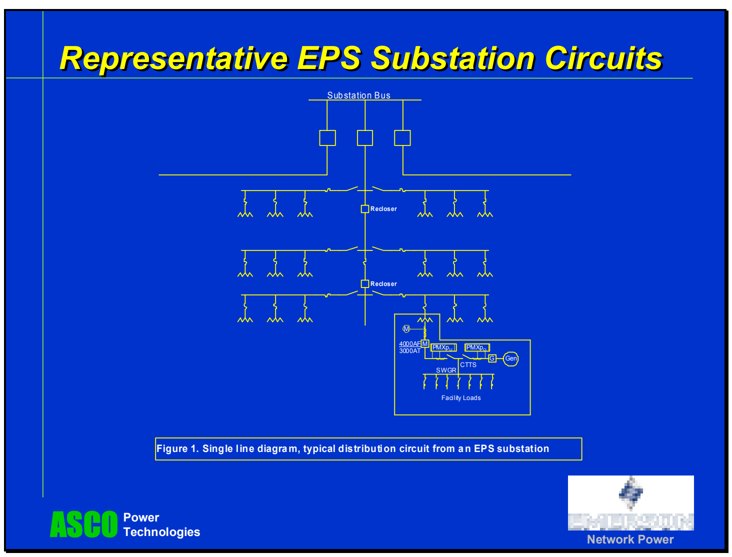
- DR < Facility Demand
- No impact on Network Protectors



ASCO Power Technologies

Network Power


Emergency/Standby System
ATS
Gen
Critical load
ATS
Gen
Critical load
ATS
Peaking load
ASCO Power Technologies
Network Power


Representative EPS Substation Circuits
Substation Bus
Recloser
Recloser
M
4000AF
3000AT
M
PMXp
PMXp
G
Gen
CTTS
SWGR
Facility Loads
Figure 1. Single line diagram, typical distribution circuit from an EPS substation
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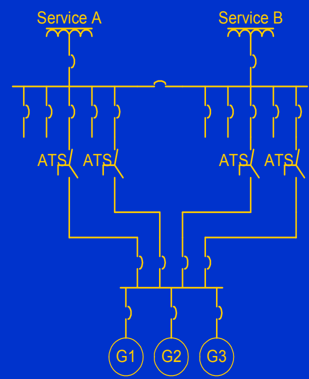
Emergency/Standby System



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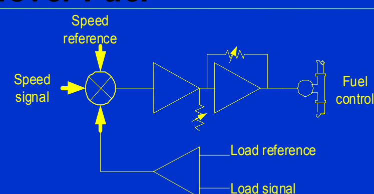
Prime Mover Fuel



- Fuel flow regulation produces speed control
- Regulation controls power developed at a constant speed

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Generator Voltage

- Terminal Voltage
- VARs

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Generator Excitation

- Regulation of excitation controls terminal voltage
- Regulation controls VARs produced at a constant voltage

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Relay Scheme

- Permissive
- Protective

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Control at Point of Interconnect

- Getting Connected
- After Connection

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Permissive Relaying

- Preclude synchronizing and paralleling until both sources are adequate and acceptable
- Voltage
- Frequency
- Phase angle

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Getting Connected

- Passive synchronizing
- Active Synchronizing

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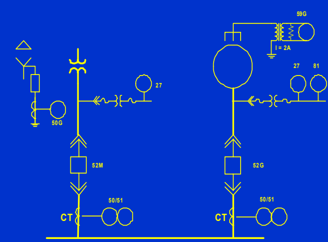
Momentary Paralleling

- Overlap time < 100 ms
- Passive Synchronizing
- Permissive Relaying



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Passive Synchronizing

- Establishes acceptability of both sources
  - 95% < Bus V < 110%
  - 59Hz < Bus F < 61 Hz
- Senses Synchronism
  - Δ Volt < 10%
  - Δ F < 0.2 Hz
  - Δ Θ < 10 deg.

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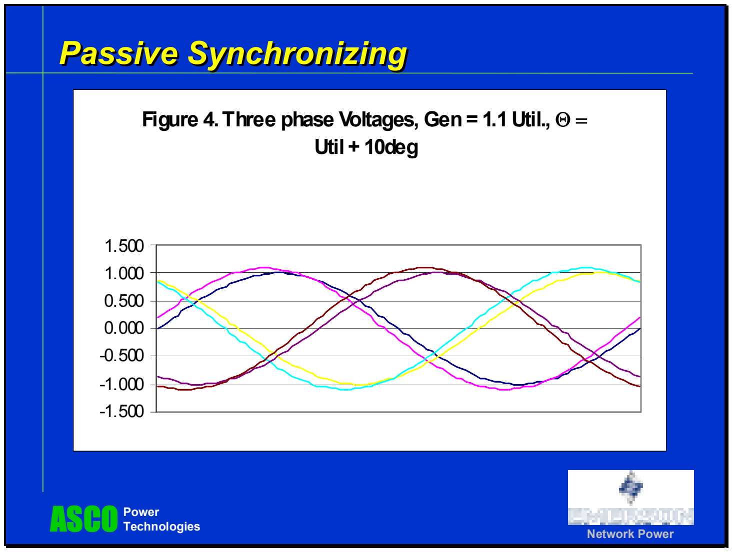
Passive Synchronizing
Figure 4. Three phase Voltages, Gen = 1.1 Util., Θ = Util + 10deg
1.500
1.000
0.500
0.000
-0.500
-1.000
-1.500
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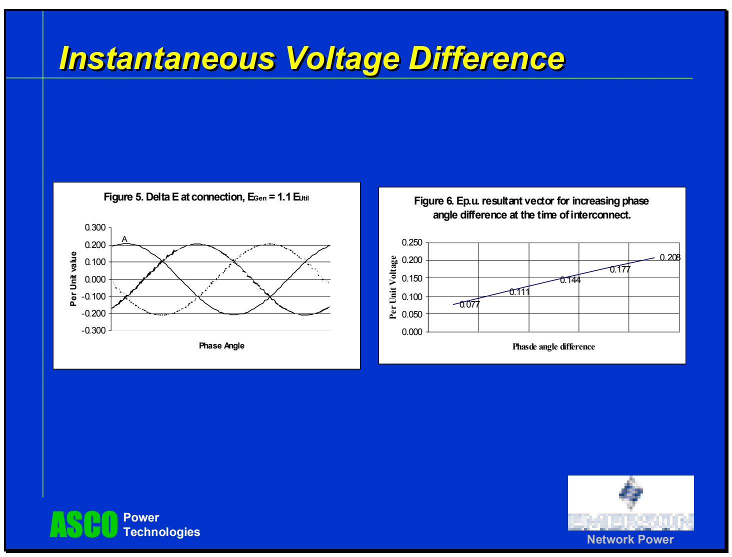
Instantaneous Voltage Difference
Figure 5. Delta E at connection, EGen = 1.1 EUtil
Per Unit value
Phase Angle
Figure 6. Ep.u. resultant vector for increasing phase angle difference at the time of interconnect.
Per Unit Voltage
Phasde angle difference
0.077
0.111
0.144
0.177
0.208
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Active Synchronizing

- Establishes acceptability of both sources
  - 95% < Bus V < 110%
  - 59Hz < Bus F < 61 Hz
- Produces Synchronism
  - Controls fuel to match frequency and phase angle
  - Controls excitation to match voltage

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Synchronizing Transients

- Passive Synchronizing
  - < 0.21 pu V
- Active Synchronizing
  - < 0.02 pu V

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After Connection

- Insufficient capability to pull out of synchronism
- Fuel controls kWh production
- Excitation controls kVARh production

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Protective Relaying

- Respond to unacceptable conditions to initiate an alternative operation(i.e. separate the power sources)
- Directional current & power
- Over current
- Sequence voltages & currents
- Voltage & frequency

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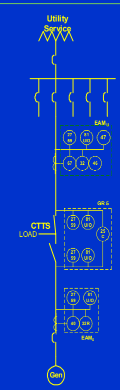
Extended Paralleling

- Relaying
  - Permissive
  - Protective
- Control
  - Fuel = kWh
  - Excitation = kVARh



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New Communications Solutions

SiteWEB™ Product Line

- SiteWEB™
  - Telephone Interface Module
  - SiteWEB Browser
  - 3rd Party Software
    - ASCO VPI Custom
  - Hardware
    - Telephone Interface Module
    - Power Manager Transducer
    - Communications Module (Acc. 72A)
    - Printer Interface Module
    - Thin Web Server

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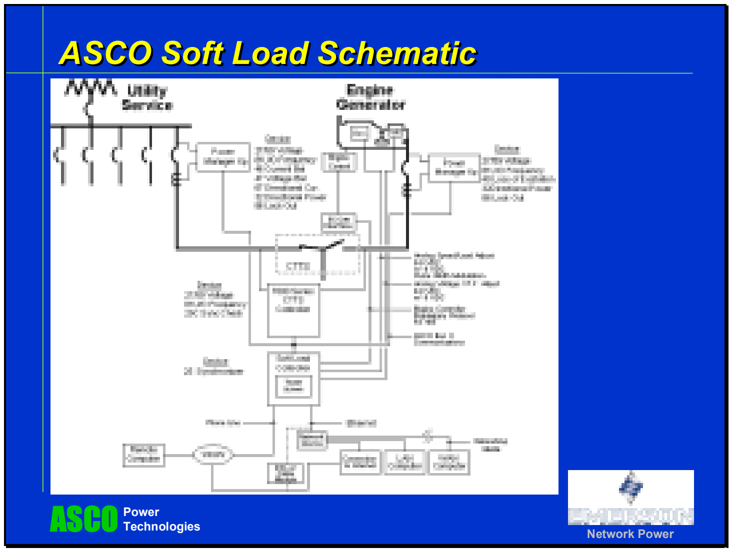
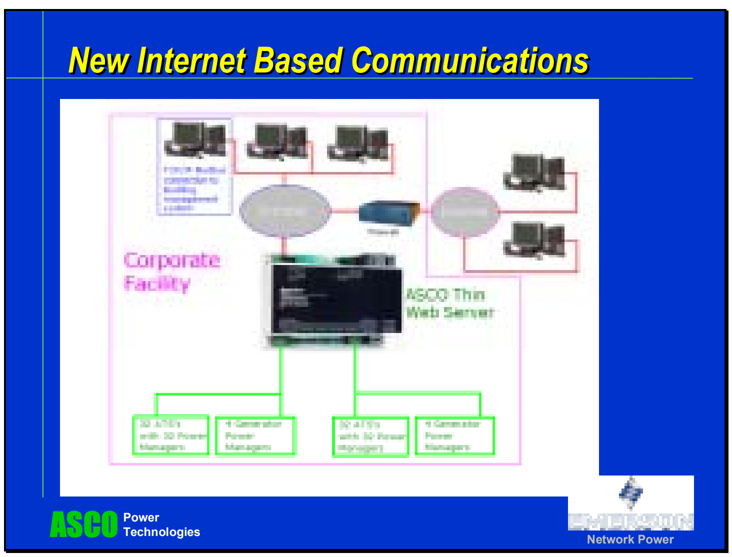
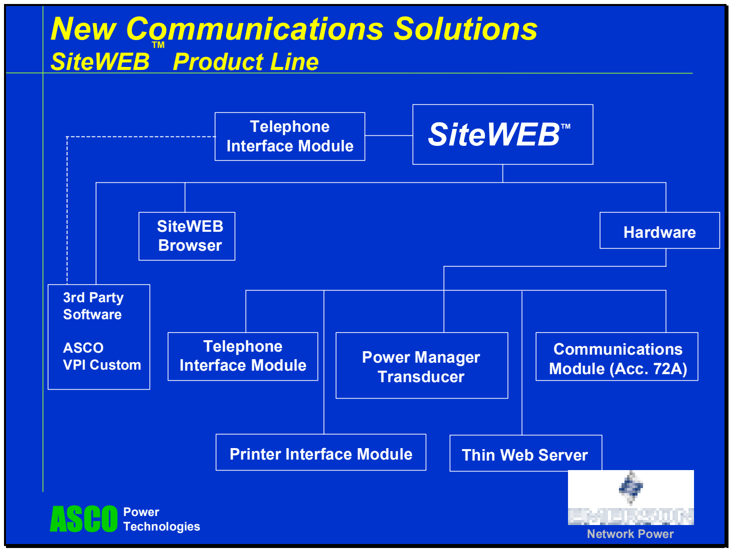
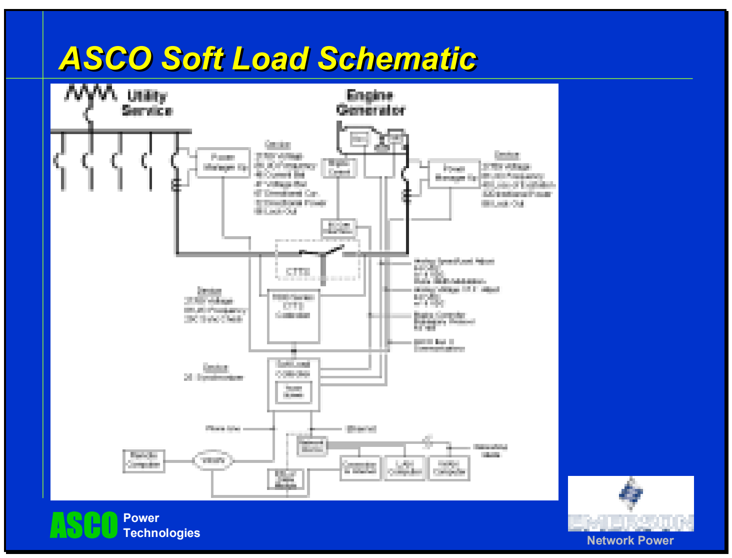
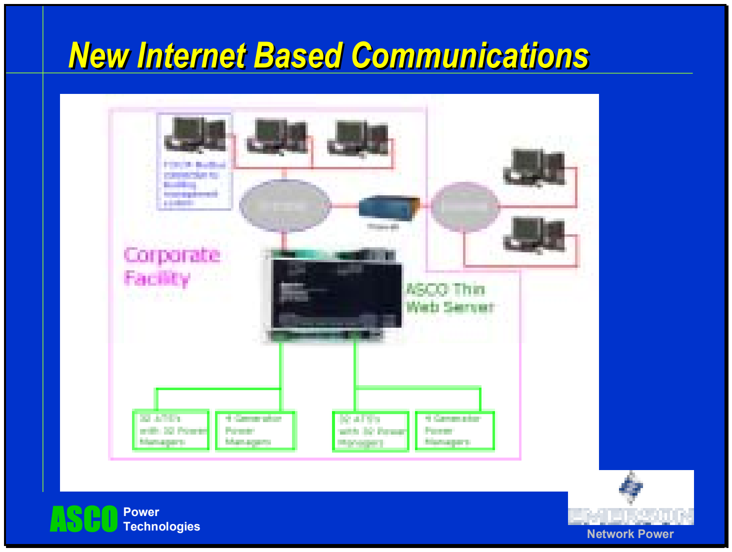
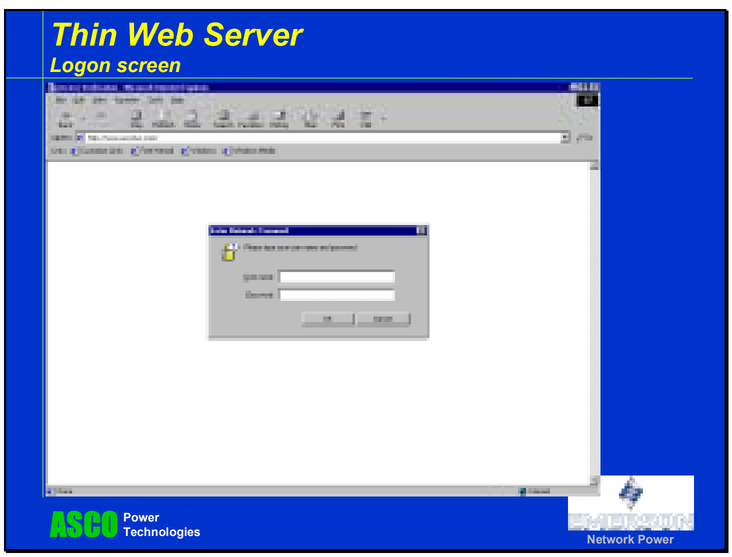

ASCO Soft Load Schematic
Utility Service
Engine Generator
ASCO Power Technologies
Network Power


New Internet Based Communications
Corporate Facility
ASCO Thin Web Server
ASCO Power Technologies
Network Power


New Communications Solutions
SiteWEB™ Product Line
Telephone Interface Module
SiteWEB™
SiteWEB Browser
Hardware
3rd Party Software
ASCO VPI Custom
Telephone Interface Module
Power Manager Transducer
Communications Module (Acc. 72A)
Printer Interface Module
Thin Web Server
ASCO Power Technologies
Network Power


ASCO Soft Load Schematic
Utility Service
Engine Generator
ASCO Power Technologies
Network Power


New Internet Based Communications
Corporate Facility
ASCO Thin Web Server
ASCO Power Technologies
Network Power


Thin Web Server
Logon screen
ASCO Power Technologies
Network Power

Thin Web Server

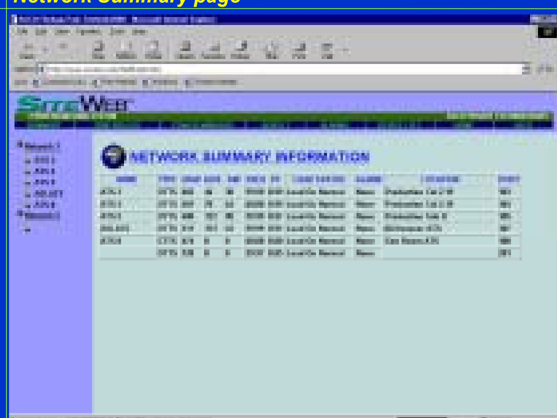
Main information / navigation page

ASCO Power Technologies

Network Power

Thin Web Server

Network Summary page



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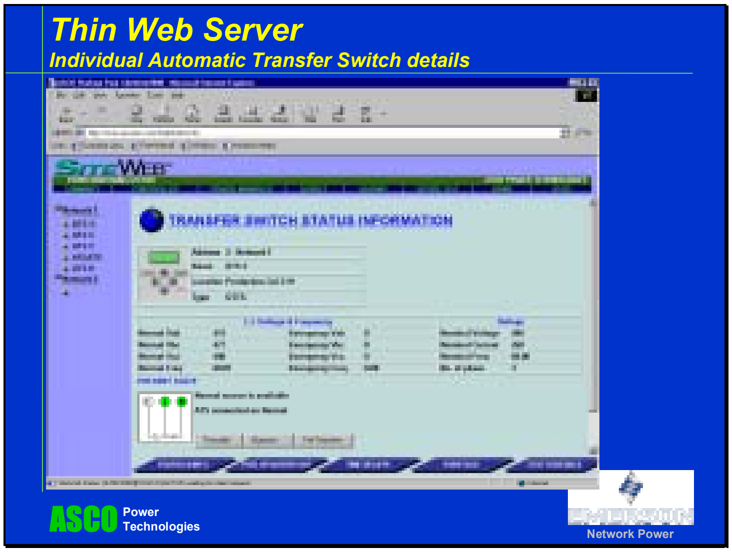
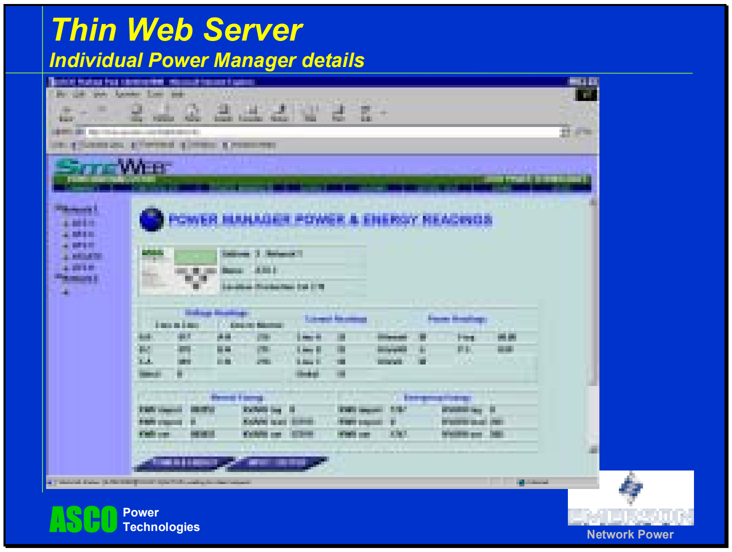
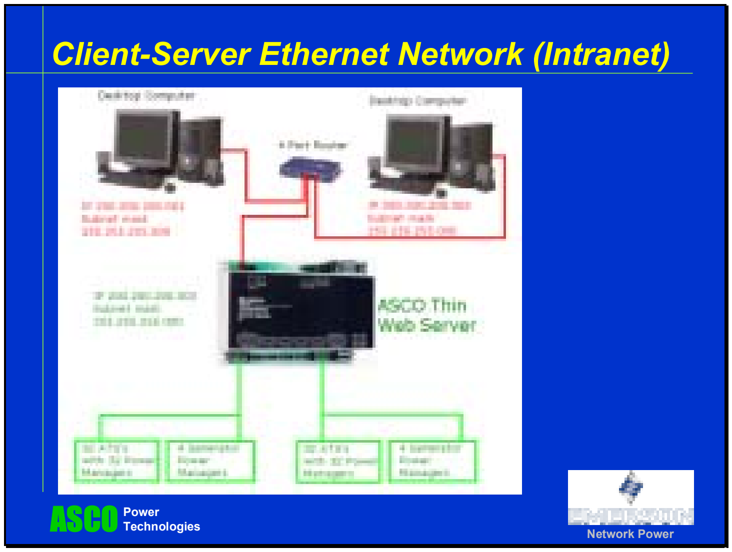

Thin Web Server
Individual Automatic Transfer Switch details
TRANSFER SWITCH STATUS INFORMATION
ASCO Power Technologies
Network Power


Thin Web Server
Individual Power Manager details
POWER MANAGER POWER & ENERGY READINGS
ASCO Power Technologies
Network Power


Client-Server Ethernet Network (Intranet)
Desktop Computer
4 Port Router
Desktop Computer
ASCO Thin
Web Server
ASCO Power Technologies
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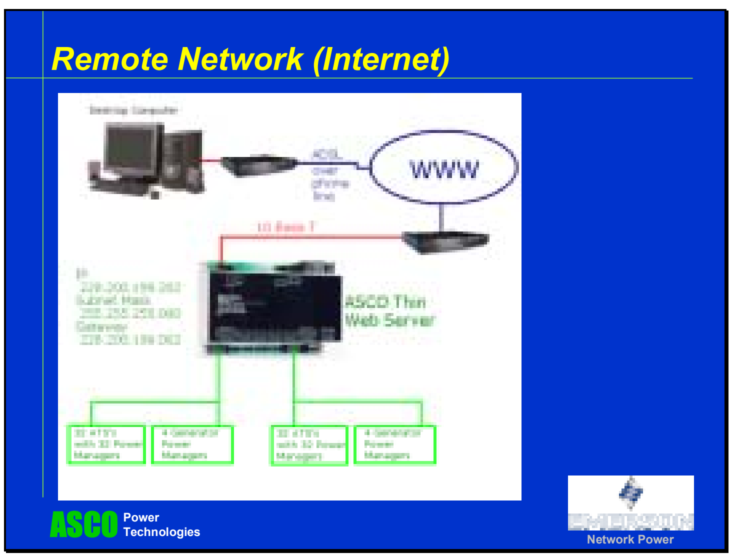
Remote Network (Internet)
Desktop Computer
ADSL
over
phone
line
WWW
10 Base T
ASCO Thin
Web Server
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Summary

- Interconnect readily achievable
- Responsive control strategies
- Adequate protection
- Adds to Grid reliability

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- Wharton, NJ 07885
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  - 973 361 6349 (home)
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  - JMDaleyPE@worldnet.att.net (home)

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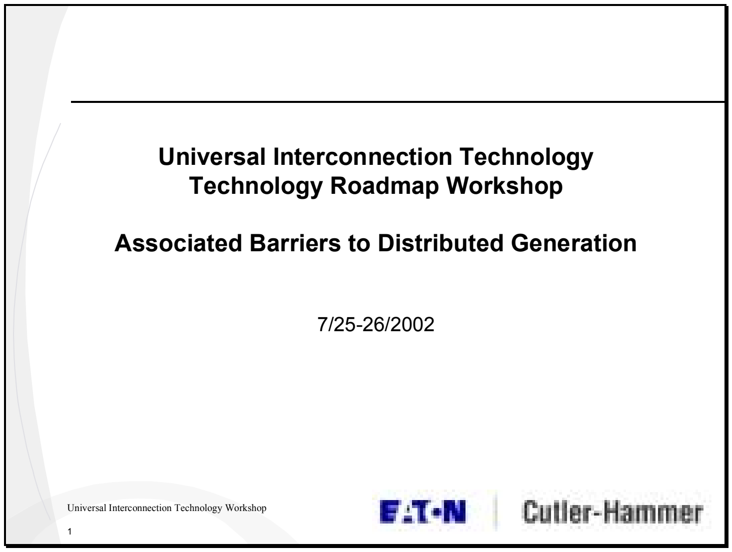
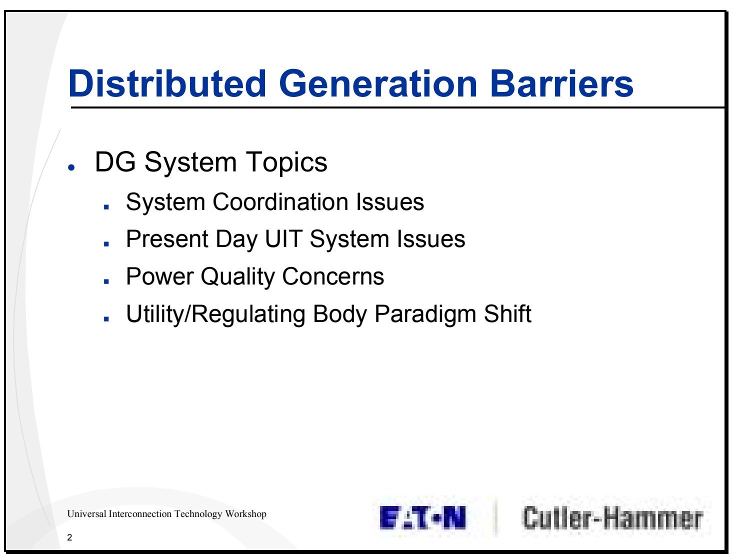
"Associated Barriers to Distributed Generation," Robert D. Hartzel, PE, Cutler-Hammer Inc.





Distributed Generation Barriers

- System Coordination Issues
  - Fault Current Considerations (Site by Site)
    - Equipment must be sized properly
  - Proper Coordination (Site by Site)
    - Breaker Trip Units
    - Relay Settings
      - Voltage & Frequency
      - Reverse Power, Negative & Positive Sequence
      - Synch Check & Others
    - Alarm Settings
    - Recloser Coordination

Distributed Generation Barriers

- Possible Solutions
  - Study US power grid
    - Determine if a general Fault Current Distribution exists
      - 70% of System<65kA
      - 90% of System<100kA
      - 100% of System<200kA
    - Determine if there are common related factors
      - Application voltage, primary transformer size, other

Distributed Generation Barriers

- Present Day UIT System Issues
  - Advantages
    - Lower Cost than Traditional Systems
    - Greater Functionality
  - Disadvantages
    - Complexity
      - Higher level startup engineer required
      - Customer service personnel not PC savvy
    - Customer Education (direct & indirect)
    - Customer lack of knowledge of Utility Programs

Distributed Generation Barriers

- Possible Solutions
  - Increase Plug & Play Capabilities
    - Provide Governor & Voltage Regulator list
    - Provide Prime Mover list
  - Friendly On-Board Assistance
    - Select system defaults based on above selection
    - Develop application troubleshooting database
  - Develop customer friendly software
    - Lead customer to system issue

Distributed Generation Barriers

- Possible Solutions
  - DG Customer Education
    - What is DG?
    - What system considerations must be addressed?
      - Positive & negative examples
    - What are the available Utility Programs?
    - Forms of DG: Pros & Cons
      - Prime Movers, Microturbines, Fuel Cells, etc.
    - Information readily available: All State web sites

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Distributed Generation Barriers

- Power Quality Concerns
  - Harmonics
    - Loads can cause harmonic issues
    - Magnitudes change with source impedance
      - Higher source impedance yields higher harmonics
    - Flicker
  - Ferroresonance
    - Equipment damage
      - Overvoltages and Core Saturation

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Distributed Generation Barriers

- Possible Solutions
  - Develop customer incentive programs
    - Specify quality of drive inverters (6, 12 & 18 pulse)
    - Educate customers on Application Issues
      - Paralleled sources provide lowest impedance

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Distributed Generation Barriers

- Utility/Regulating Body Paradigm Shift
  - No incentive for Utilities to use DG
    - Distribution only Utilities
      - Not permitted to Dispatch Power
      - Required to serve all customers
    - Generation only Utilities
      - Not interested in small DG systems
    - Transmission only Utilities
      - Too many dispatching decisions to make w/o DG

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Distributed Generation Barriers

- Possible Solutions
  - Determine who should have incentive to use DG
  - Determine how DG should be used
    - Support peak power requirements
    - Defer Transmission line cost
    - Pass value back to utility customers
      - Buying power from DG customers
      - Lowering non-DG customer bills

Distributed Generation Barriers

- Utility/Regulating Body Paradigm Shift
  - Distribution Utility Issues
    - Not designed for bi-directional power flow
    - Current Stability Models show negative impact
    - Build distribution & transmission to meet 100% load
      - Includes Peak & Safety Margin Power

Distributed Generation Barriers

- Possible Solutions
  - Develop bi-directional distribution system model
    - Synchronism Check Relays
  - Create new Stability model using DG

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Distributed Generation Barriers

- Possible Solutions
  - Create new power flow models using DG
    - May increase Distribution cost
    - Should decrease Transmission cost
    - Should decrease central plant cost
    - Should decrease overall energy cost
  - Create new tariff structures to support DG versus building T&D

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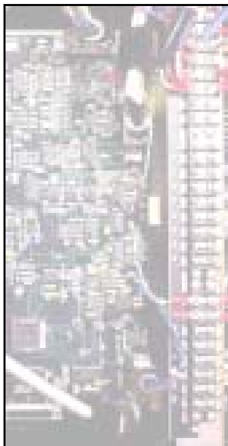
"Overview of Currently Available UIT Systems," Paul E. Sheaffer, Resource Dynamics Corp.



Overview of Currently Available UIT Systems

U.S. Department of Energy
Universal Interconnection Technology Workshop
July 25-26, 2002 Chicago, IL

Paul Sheaffer, Director - Energy Technology
Resource Dynamics Corporation, 703-356-1300
sheaffer@rdcnet.com

Resource Dynamics Corporation

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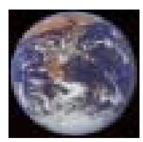
Outline



- The interconnection system
- The Universal Interconnection Technology concept
- Current UIT-like offerings

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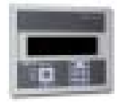
The Interconnection System

- The interconnection system performs the functions necessary to maintain the safety, power quality, and reliability of connected area EPSs and DERs
- System complexity depends on the level of interaction required between the DER and the EPS

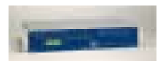
Interface Configurations Vary by DER Applications

	No Interconnection	Isolated DER Operation With Automatic Transfer To Area EPS	Parallel Operation To Area EPS, No Power Export	Parallel Operation To Area EPS, Power Export To Area EPS
Baseload	✓	✓	✓	✓
Cogeneration	✓	✓	✓	✓
Peak Shaving		✓	✓	✓
Emergency/Backup		✓	✓	✓
Premium	✓		✓	✓
Remote	✓			

Interconnection Systems Can Include the Following Components:



- Exciter control system for the generators,
- Synchronizer for the reliable transfer of power between the generators and the grid,
- Automatic transfer switch control,
- Import/export control,
- Protective relay functions,
- Metering, and
- Remote communications.



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The U.S. DG Interconnection System Market is Potentially Great in Size

- Engines and Combustion Turbines > 100 kW in size
  - engines (184,000 units; 87,000 MW)
  - turbines (3,000 units; 58,000 MW)
- Microturbines < 100 kW in size for premium power, peak shaving, backup, power export
  - 1,200 units; 40 MW
- Fuel cell systems used for prime power
  - 200 units; 40 MW

It is important to not ignore options for interconnecting the many existing small emergency generators

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A Universal Interconnection Technology (UIT) Would:

- Define a standard architecture for functions to be included in the interconnection system,
- Meet the needs of the DG Interconnection market,
- Make DER Installations
  - cheaper,
  - quicker,
  - more reliable,
- And will also provide benefits to distribution companies.

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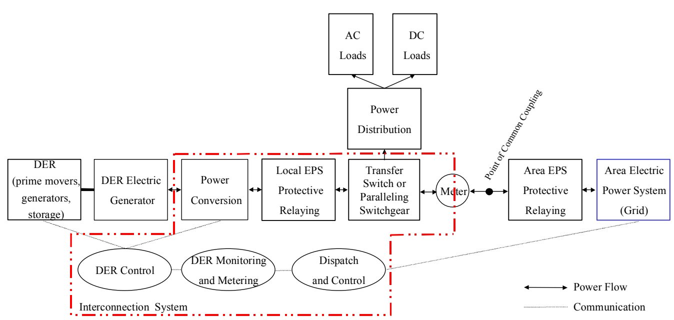
Interconnection Schematic (1)



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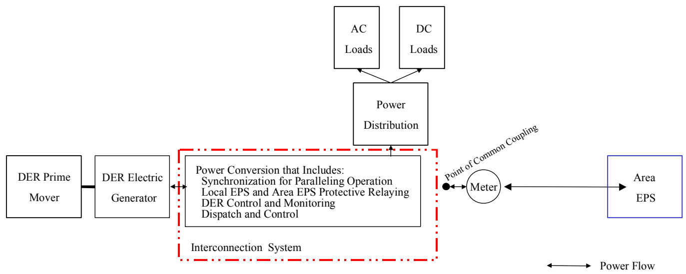
Interconnection Schematic (2)



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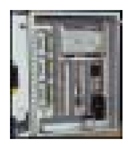
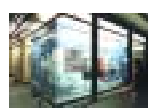
There are Two Types of UIT-Like Systems Currently in Development

- Traditional *non-inverter based pre-engineered systems* that allow for synchronization and parallel operation with the grid (switchgear)



- *Inverter based* UIT-like systems for prime movers with DC or high frequency AC output (i.e. PV systems and fuel cells)



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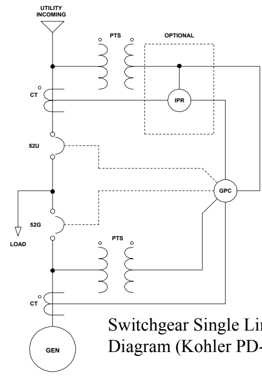
Traditional Non-Inverter Based Switchgear

- Pre-engineered structures that contain the functions necessary for synchronization and parallel operation with the grid:
  - operator interface,
  - controls,
  - protective relays,
  - circuit breakers,
  - synchronization,
  - and much more.
- Generally used for DER units with more traditional AC output.



Switchgear Single Line Diagram (Kohler PD-100)

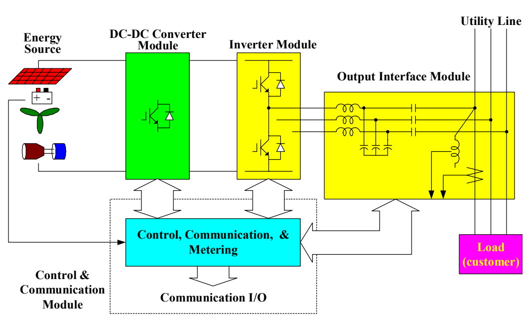
Inverter Based Systems

- Designed for use with prime movers with DC or high frequency AC output (i.e. PV systems, fuel cells, and microturbines).
- In the future, inverter based interconnection systems may be applied to standard reciprocating engine gensets.

Reciprocating Engine Inverter-based System

- Benefits
  - Higher efficiency, lower emissions at part-load
  - Better power quality
- Honda EU3000is (3 kW)
  - 200 volts at 14-17 Hz
  - Rectified to 12 volts
  - Inverted

Universal Inverter Modular Building Blocks



Issues Current Inverters Must Address to Meet the Requirements of a UIT

- Switching device ratings (and associated reliability issues)
- Transformers (and associated design limitations)
- Limitations on voltages that can be attained
- Creation of high levels of harmonic distortion
- Lower cost
- Control limitations

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Some Currently Available UIT-Like Systems

Company	Unit	Inverter	Non-Inverter	Electrical Specification
Advanced Energy Systems	*MM-5000 – Grid-Connected MultiMode Power Conversion System*	X		5 kVA
	GC-1000 1kW Grid-Connected Photovoltaic Inverter	X		1 kVA
AstroPower	*SunChoice Program*	X		8.5 kVA
Ballard	*EcoStar Power Converter*	X		Up to 110 kVA
Cummins Power Generation	*PowerCommand Digital Paralleling Equipment*		X	Up to 2,500 kVA
Detroit Diesel	*Spectrum SD-100*		X	Up to 2,400 kVA
Encorp	enpower-GPC powered "paralleling switchgear"		X	800-5000 amp
Fire Wind and Rain Technologies, LLC	*Power Streak Inverter*	X		5kVA
Kohler	*PD-100 Switchgear*		X	Up to 2,500 kVA
Thomson Technology	*Distributed Generation Switchgear System/ GCS 2000-DG System*		X	Up to 4,000 amp
Vanner Incorprated	*RE Series Inverters*	X		5.6 kVA
Xantrex	*Grid Tie Inverters*	X		Up to 125 kVA
ZTR/Shallbetter	*DGX Switchgear*		X	Up to 4000 amp

Several systems integrate components from multiple manufacturers

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Kohler PD-100

- 20-2,000 kW 800-4,000 amps
- New units and retrofits
- 1/3 the size of typical switchgear
- Modes of operation
  - ATS (closed, open, or soft load)
  - Interruptible rate
  - Peak shaving
  - Export to utility
- Uses Encorp controller

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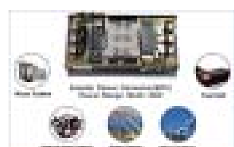
Ballard Ecostar Power Converter



- 10 kW - 1 MW size range
- Variety of “prime movers”
- Modes of operation
  - Grid mode and stand-alone mode operation
  - Grid mode and stand-alone mode transition
  - Stand-alone mode to grid mode transition
  - Standby generator start/stop, remote wake-up, and standby function
  - Multi-unit capability up to 1 MW for grid and stand-alone operation
  - Reliable synchronization to the grid
  - Remote monitoring/controls/dispatch

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Built-in Systems

- Many DER manufacturers have been either building in, or offering as an option, some of the key interconnection equipment components as part of their DER genset offerings
- Thus far, DER manufacturer systems are the only systems to be certified though California Energy Commission's Rule 21 certification though it seems likely that UITs could benefit from this process as well

Rule 21 Certified Units

- Capstone
  - Model 220 and 60
- PlugPower
  - 5 kW PEM fuel cell
- Both have built-in UIT-like functions
- Currently, interconnection companies have not approached California regarding Rule 21

"Universal Interconnection Technology," Dr. Robert Wills, PE, Advanced Energy Inc.

Advanced Energy *The Power of Choice™*

Universal Interconnection Technology

Dr. Robert Wills, P.E.

VP Engineering

Advanced Energy, Inc.

Wilton, New Hampshire

www.advancedenergy.com

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Advanced Energy *The Power of Choice™*

Small is Beautiful

We need methods and equipment which are:

- **Cheap enough so that they are accessible to virtually everyone;**
- **Suitable for small scale application; and**
- **Compatible with man's need for creativity**

(E.F. Schumacher, 1973)

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Advanced Energy

The Power of Choice™

Why Distributed Generation?

Security

- Power Supply Reliability
- Power Quality
- Immunity from Attack

The National Research Council has recommended that we "Develop, Test and Implement an intelligent, adaptive electric-power grid"

Advanced Energy

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Intelligent, Adaptive Power

Recommendation 16: Technology should be developed for an intelligent, adaptive power grid that combines a threat-warning system with a distributed-intelligent-agent system. This grid would be able to rapidly respond with graceful system failure and rapid power recovery. It would make use of adaptive islanding—a concept employing fast-acting sensors and controls to "island" parts of the grid as the rest comes down—and technologies such as storage units positioned at key points to minimize damage during shutdown. The system would need to be able to differentiate between a single component failure and the kind of concurrent or closely coupled serial failures at several key nodes that would indicate the onset of a concerted attack.

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The Environment (& More Schumacher)

- ***Atmospheric Pollution***
  - **Small scale operations, no matter how numerous, are always less likely to be harmful to the natural environment than large-scale ones, simply because their individual force is small in relation to the recuperative forces of nature.**
- ***Reduced use of Non-Renewable Resources***
  - **It is clear that the "rich" are in the process of stripping the world of its once-for-all endowment of relatively cheap and simple fuels.**

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Lower Costs!

- **Lower Design Costs**
- **Shorter Time to Market**
- **Standardized Components**
- **Higher Efficiencies(?)**
- **Heat Recovery (CHP)**
- **Lower Distribution Losses**

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Summary of *Why -> How*

DER Devices must be:

- **Secure (providing reliable, high quality power and immunity from attack)**
- **Flexible (capable of feeding the grid and operating in intentional islands)**
- **Efficient & Cost-effective**
- **Renewable & Sustainable**
- **Safe**

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Technology - Some Issues are Solved:

- ***1547 will specify voltage and frequency trips***
- ***Current controlled inverters are common – THD requirements can be met***
- ***Adequate anti-island techniques have been developed***

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… And Some are Not:

- ***Multi-Inverter Islanding is not addressed***
- ***Methods of controlling microgrid and intentional islands***
- ***Standard Procedures for Testing***
- ***DC Injection & DC on the grid***
- ***1547 Certified Controllers***

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Current Myths

- ***Voltage and Frequency Protective Relaying can provide reliable anti-islanding protection***
- ***UL1741 Island Tests are sufficient to ensure multi-inverter protection***
- ***Induction Generators cannot Island***
- ***Islanding is unlikely to occur***

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Islanding - Key Issues

- *The basic problem is solved and becoming well understood*
- *AEI Patent covers feedback and acceleration concepts (the Sandia Methods)*
- *Need to prove viability at high penetration*
- *Need to model stability in the wide-area grid*
- *Multi-inverter systems / Multiple methods*
- *Testing (test setups, procedures, motor tests)*

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Anti-Islanding Primer

- *Passive Trips (Voltage and Frequency)*
- *Phase Jump Detection*
- *Harmonic Monitoring*
- *Impedance Measurement/Power Shifting*
- *Reactive Power Feedback*
- *Real Power Feedback*
- *Direction and Acceleration*

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Islanding - Known Problems

- ***Flicker***
- ***Dilution of power shifting methods***
- ***Thresholds***
- ***Quantization***
- ***Inadequate feedback***
- ***Incompatibility of different methods***

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Islanding Conclusion

- ***Ultimately, we need to adopt a method, not a performance test***
- ***We must base future work on theory, not on experimentation***

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DC Injection

- ***Many inverters can inject DC onto the line - we need to alter utility procedures***
- ***Some utilities are questioning non-transformer-isolated designs***
- ***Need to distinguish between HF isolation transformers with DC output and low frequency transformers***
- ***Redundant voltage detection might be the solution***

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Microgrids and Intentional Islands

- ***Need to agree on how devices will work together via communications and the electrical interface***
- ***Must allow for Steady State, Transient and Fault Conditions***
- ***AEI has been working on this problem for three years with Sandia***

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Certified Controllers

- ***UL Certification Costs are high***
- ***Testing is required for every model***
- ***Our theoretical understanding is becoming sufficient to allow type testing of a controller based on control and anti-islanding methods***
- ***We believe that this is the path to universal interconnection technology***

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Communications

- ***P1614 Draft Guide for Monitoring, Information Exchange and Control of Distributed Resources Interconnected with Electric Power Systems***
- ***Operation/monitoring/Control/Scheduling/ Resource Allocation***
- ***The keys are object modeling and security***
- ***Please join the working group!***

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Recommended Areas for Research

- ***A standard anti-islanding method that is proven in the multi-inverter case***
- ***Control schemes for microgrids and intentional islands***
- ***Certified controllers***
- ***Test procedures***
- ***Communications protocols and object model***
- ***Cryptographic techniques such as SSL for use in micro-controller-based DER communications devices***

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Conclusion

There is a wisdom in smallness if only on account of the smallness and patchiness of human knowledge, which relies on experiment far more than on understanding.

(E.F. Schumacher)

Universal Interconnection Technology Workshop 20

Appendix B. List of Participants

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Appendix C. Agenda for Universal Interconnection Technology Workshop

Universal Interconnection Technology Workshop

Venue:
Embassy Suites Chicago-Downtown/Lakefront
511 North Columbus Drive, Chicago, IL 60611
Tel: 1-312-836-5900
Fax: 1-312-836-5901

Goals of Workshop:

- Define Universal Interconnection Technology (UIT)
- Describe UIT functions and features
- Build foundation for UIT development
- Solidify an industry UIT stakeholder group

Agenda

Day 1 – Thursday, July 25, 2002

7 – 8 a.m.	Continental Breakfast
8 a.m.	Welcome (Joseph Galdo, DOE DEER)
8:10 a.m.	Background Introduction of Participants UIT Concept and Benefit Overview Review of Agenda

Exercise No. 1: UIT Functions, Needed Functionality, and Features

8:30 – 10 a.m. Presentations

- Dr. Sam Ye, GE Global Research Center, "Universal Interconnect Needs and Trends"
- Scott Castelez, Encorp, "Emerging DER Networks"

10 a.m. Break

10:30 a.m. – 12:30 p.m. Participant Discussion

- What minimum set of functions should be included in a basic interconnection system? What are the optional functions?
- Given engineering trade-offs, what are the key features (e.g., interoperability and compatibility, flexibility, scalability and expandability, reliability, survivability, affordability) that a modular UIT design should focus on?

12:30 p.m. Working Lunch

Exercise No. 2: Current Practice with Packaged Systems

1:30 – 3 p.m. Presentations

- James M. Daley, PE, ASCO Power Technologies, “www and Facility Electric Power Management”
- Robert D. Hartzel, PE, Cutler-Hammer Inc., “Associated Barriers to Distributed Generation”
- Paul E. Sheaffer, Resource Dynamics Corp., “Overview of Currently Available UIT-Like Systems”

3:00 p.m. Break

3:30 – 5 p.m. Participant Discussion

- How can we design a UIT system so that utilities embrace DER?

5 p.m. Adjourn Day 1

Day 2 – Friday, July 26, 2002

7 – 8 a.m. Continental Breakfast

8 a.m. Day 1 Review, Goals for the Day

Exercise No. 3: Technology Challenges and R&D Solutions

8:30 – 10 a.m. Presentations

- Dr. Robert Wills, PE, Advanced Energy Inc., “Universal Interconnection Technology”

10:30 a.m. Break

11 a.m. – 12:30 p.m. Participant Discussion

- How might the UIT functions be organized into a block diagram (modules)?
- How would individual businesses benefit from the development of a modular UIT?
- At what DER unit size(s) might the UIT need different designs or technology development?

12:30 p.m. Working Lunch

Exercise No. 4: Moving Forward

1:30 – 3 p.m. Next Steps for the UIT Roadmap and Wrap-Up, Participant Discussion

- What should the UIT development effort look like? What are the roadblocks to accomplishing this development?
- Where do we go from here (technology roadmap versus another workshop versus small design group, standardization of interfaces between modules, etc.)?

3 p.m. Adjourn

APPENDIX D. Contact Information

For more information about the U.S. Department of Energy, Distributed Energy and Electric Reliability (DEER) Program, and Distribution and Interconnection R&D activities, visit www.eren.doe.gov/distributedpower/.

For additional information about the UIT effort, contact:

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13. ABSTRACT *(Maximum 200 words)*

The Universal Interconnection Technology (UIT) Workshop — sponsored by the U.S. Department of Energy, Distributed Energy and Electric Reliability (DEER) Program, and Distribution and Interconnection R&D — was held July 25-26, 2002, in Chicago, Ill., to:

- Examine the need for a modular universal interconnection technology
- Identify UIT functional and technical requirements
- Assess the feasibility of and potential roadblocks to UIT
- Create an action plan for UIT development.

These proceedings begin with an overview of the workshop. The body of the proceedings provides a series of industry representative-prepared papers on UIT functions and features, present interconnection technology, approaches to modularization and expandability, and technical issues in UIT development as well as detailed summaries of group discussions. Presentations, a list of participants, a copy of the agenda, and contact information are provided in the appendices of this document.

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